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ASIAN DEVELOPMENT BANK

ENERGY EFFICIENCY SUPPORT PROJECT

SECTOR ANALYSIS
PETROCHEMICAL INDUSTRY

SUPPORTED BY
GOVERNMENTS OF THE NETHERLANDS AND INDIA

EXECUTING AGENCY
THE INDUSTRIAL CREDIT AND INVESTMENT CORPORATION OF INDIA LIMITED

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Executive summary

The Government of Netherlands (through the Asian Development Bank) and the Government of India has jointly launched a project entitled 'Energy Efficiency Support Project (ESP)' to look into various aspects of energy and environmental issues pertaining to the Indian industry. The project comprises of two distinct phases. Phase-I of the project deals with identification of industry sectors where there is a substantial scope for energy saving and pollution reduction through energy efficiency investments. Phase-II of the project primarily covers various initiatives like undertaking energy and environmental audits, feasibility studies, training programmes and promotional campaigns for industry sectors identified under the phase-I of the study. One of the sectors to be covered for detailed analysis by TERI under phase-I is the petrochemical sector.

The petrochemical sector plays an important role in the industrial strategies and economic growth of a country. The rate at which the sector has grown in India is quite remarkable, maintaining a double digit figure for the last few decades. There are more than 50 products based on petrochemical input. However, in order to give a focused assessment, two downstream petrochemicals have been selected for detailed review in this study : **Poly Vinyl Chloride (PVC)** which has the largest market share among plastics consumed in India and **Polyester (Polyester Filament Yarn (PFY)/Polyester Staple Fibre (PSF))** the most common synthetic raw material for textiles. Both these products are particularly energy intensive and account for a major share of total energy consumption in the petrochemical sector.

In this study, a review of the current scenario was carried out for the two downstream products based on historical performance and trends, distribution of ownership and analysis of energy consumption pattern. The study also covers the status of manufacturing technologies, overall performance of the sector with respect to capacity utilisation and specific energy consumption and identifies some major energy saving opportunities within the selected sub-sectors. Emission standards and pollution control techniques have also been dealt with in this report.

Polyvinyl chloride (PVC)

There are seven major producers of PVC in India, with a total installed capacity of about 550,000 TPA. The domestic consumption has shown a remarkable growth rate of about 32% during the last four years, and total production in 1994-95 was 442,000 tonnes. PVC production is predominantly in the private sector with only one major producer in the public sector. With huge demand from construction and housing sector, the consumption of PVC is expected to show a steady growth rate of atleast 12% in the future.

PVC is a fairly energy intensive sector and the net specific energy requirement for manufacture of PVC from vinyl chloride monomer (VCM) is about 2445 Mcal/tonne in Indian plants. For a production of 442,000 MT in 1994-95 the total net energy consumption in the PVC sector works out to be about 1.1×10^6 Gcals. The share of energy cost to the total production cost varies with the size and vintage of the plants and is in the range of 5 to 8%. The common forms of energy used in PVC manufacture are electricity, furnace oil and natural gas, with electricity accounting for 58% of the total energy use by this sector.

Most PVC plants in India have been set up over a decade ago. The plants are of sub-optimal size and are based on obsolete technology. It has been estimated that the total energy saving potential in this sector is 10-15% of the total energy use. Some of the major energy saving measures include installation of higher productivity reactors, use of latest control systems, incorporation of new clean reactor technology, improved stripping process, new cyclone dryer system and improvements in steam distribution system and condensate recovery.

The liquid effluent stream from PVC plants has a high percentage of volatile chlorinated hydrocarbons which have to be treated separately. Containment of VCM and its monitoring is very important in PVC plants. All the plants, have effluent treatment facilities. However, there is scope for further reduction in VCM exposure by employing clean reactor technology and improved stripping methods.

Most of the energy conservation measures involve drastic changes in technology and require major capital investments. Till recently, PVC was in short supply and had to be imported to meet domestic demand. This coupled with high import duties, did not offer much incentive to the producers to reduce energy costs and become more competitive. However, now with the liberalisation of the economy and the reduction in import duties, units have to reduce energy costs in order to become cost competitive and sustain the desired growth rate in the future.

Polyester yarn and fibre

There are several major manufacturers of polyester filament yarn (PFY) and polyester staple fibre (PSF). The industry has made rapid progress, and recorded about 13% growth rate in the last five years. The total installed capacity of PFY and PSF is about 5.33 lakh tonnes and total production in 1994-95 was 5.15 lakh tonnes. With dwindling share of cotton fabrics in the overall per capita cloth consumption, the expected future growth rate of this sub-sector is about 15% per annum. The industry is predominantly in the private sector, with only 3 units in the public and cooperative sector.

The production of polyester fibre/yarn is an energy intensive process and the specific energy consumption is estimated to be about 9181 Mcal/tonne. For a total production of 515,000 MT in 1994-95, the absolute energy consumption for the sub-sector is estimated be about 4.71×10^6 Gcals. Electricity and furnace oil are the major form of energy used. Coal is also being also used in few plants. The share of energy cost as a percentage of the total production cost, varies widely, and is in the range of 6 to 9% for most plants.

With the exception of a handful of big companies, most of the Indian polyester yarn and fibre plants are much smaller in size compared to similar plants in Korea or Taiwan. Against an average installed capacity of 35,000 to 60,000 tonnes in Korea and Taiwan, the size of an Indian plant, on an average, is about 9,000 tonnes. Higher levels of productivity and lower production costs are prerequisites for competitiveness of the sector. There is scope to achieve energy savings if about 15-20% in most plants, and thus make them more cost competitive. Some of the measures which will result in significant energy savings are upgradation of control systems, use of continuous polymerisation reactors, use of vapour absorption chiller, improvements in methanol recovery, heat recovery from stack gas and better condensate recovery.

All the PSF/PFY plants in India have effluent treatment plants. Improvements in methanol recovery from vent gases and liquid effluents could result in further saving in existing plants.

In a broader context, the deterrents to the faster growth of the industry may be classified into those which arise from inherent weaknesses afflicting it and those that stem from factors beyond its control such as government fiscal policies, trend in world raw material prices etc. The principal constraints in adoption of major energy measures are lack of adequate resources and high rates of excise and import duties. However, with increasing competition in local markets and with the entry of several large companies, the industry must make every effort to reduce cost through better energy management and improving efficiency.

Based on the comparative assessment of the 12 sectors, petrochemical sector (for the two selected downstream products) does not qualify as suitable candidate to be considered for the phase-II of the ESP.

CHAPTER 1

Introduction

1.1 Background

Petrochemicals can be broadly categorised into the following five categories:

a) Plastics

b) Synthetic Rubbers

c) Synthetic Fibers

d) Intermediates (e.g. DMT, PTA etc.)

e) Feedstocks (e.g. Ethylene, Propylene, Benzene etc.)

Feedstocks used by Indian companies are derived from naphtha or natural gas. Naphtha is more expensive than gas and is more versatile as well. Cracking of naphtha produces four building blocks - ethylene, propylene, butadiene and benzene while gas cracking only produces ethylene. It is from these feedstocks that other petrochemicals are made.

As per the Rakesh Mohan Committee report (an expert group appointed by the centre), petrochemical is one of the fastest growing sectors in India. The consumption of all major petrochemicals increased from 7.51 lakh tonnes in 1979-80 to 3.4 million tonnes in 1993-94 and is expected to exceed 7 million tonnes by 2000 A.D. The installed capacity by 2000 A.D. is likely to be over 6.3 million tonnes.

The following two approaches could be adopted for the study : process oriented and product oriented. The process oriented approach would include analysis of important unit operations like polymerisation, distillation, hydrogenation, cracking, crystallisation etc. The other approach would be to adopt a sectoral analysis of a few selected downstream products. Due to wide number of processes and diverse nature of operating parameters, the second approach is generally acceptable.

The Department of Chemicals & Petrochemicals, Ministry of Chemicals and Fertilisers, Government of India is the key agency for data on capacity, production and estimated demand of important petrochemicals. For more detailed information on a specific downstream product, there are industrial associations like the Association of Synthetic Fibre of India (ASFI) etc. However, it was found that very few petrochemical manufacturers are willing to share plant level information on processes and details of product-wise energy usage pattern.

1.2 Profile of the Petrochemical Sector

Petrochemicals play a supplemental role to the otherwise abundant supply of natural resources in India. In spite of the industry being restrained due to capacity licensing regime, most of which was abandoned only in 1991, the sector has shown consistent growth rate of almost 2-3 times the GDP during the eighties as shown in **table 1.1**

Table 1.1. Selected growth rates of petrochemical segments

Segment	Percent growth
GDP	5.7
Plastics	13.0
Synthetic rubbers	10.0
Synthetic fibres	15.0
Synthetic detergents	11.0

The production and consumption of important petrochemical segments is given in **table 1.2.**

Table 1.2. Production and consumption of major petrochemical groups in 1993-94

(in thousand tonnes)

Product/Segment	Production	Imports	Consumption
Plastics	982	460	1,362
Synthetic rubbers	44	36	80
Synthetic fibres	635	53	688
Intermediates	652	85	737
Synthetic detergent-Linear alkyl benzene (LAB)	211	31	242
Paraxylene	201	55	256

Despite the impressive growth achieved in this sector, the per capita usage of various petrochemicals is still abysmally low as shown in **table 1.3**.

Table 1.3. Per capita usage of petrochemicals

Product	1994-95	World average 1994
Plastics	1.49	15.18
Synthetic rubbers	0.12	1.61
Synthetic fibres	0.57	3.34
Synthetic detergents	0.20	1.27

It is evident that there is a large potential of growth in this sector, even if per capita consumption of petrochemical converges to the Asia average. The government has taken

several steps to boost domestic production and consumption like reducing excise duties and import duties, strengthening anti-dumping measures, reducing capital goods duty etc. As a result of these measures and future growth potential, major capacity build-ups are in the pipeline in the near future in this sector as indicated in **table 1.4**.

Table 1.4. Capacity build-up for petrochemicals

(in thousand tonnes)

Product group	Present capacity	New projects	Capacity 2000	Surplus/deficit
Plastics	1,756	27	3,602	602
Synthetic rubbers	85	6	189	-94
Synthetic fibres	575	20	1,527	321
Synthetic detergents	290	3	350	-70

Detailed energy consumption figures of different products in the petrochemical sector are not easily available. However, it is widely accepted that petrochemicals is one of the major energy intensive sectors and most plants are aware of the importance of energy conservation. A study of the specific energy consumption trend of Indian Petrochemical Corporation Limited (IPCL), one of the large integrated petrochemical producers in India show that the average specific energy index has been declining steadily from 10.1 Gcals/ton in 1981-82 to 6.92 Gcals/ton in 1992-93.

Petrochemical downstream processing units will receive a big boost as a result of the capacity additions. There is a possibility that India will become a net exporter of petrochemicals in the near future.

1.3 Overview of the downstream sub-sectors

A sectoral study of two downstream petrochemicals is presented here. Plastics and synthetic fibres are the two largest petrochemical segments in terms of gross production and turnover.

Table 1.5 gives a breakup of the production and consumption in India of some of the important plastics.

Table 1.5. Production and consumption of important plastics in 1993-94

(in thousand tonnes)

Polymers	Consumption	Production
LDPE	193	171.11
LLDPE/HDPE	345	224.81
PP	115	91.36
PS	40	40.87
PVC	413.24	358.45
ABS	24.7	15.09

LDPE: Low density polyethylene
LLDPE/HDPE: Linear low density polyethylene/High density polyethylene (swing plant)
PP: Polypropylene
PS: Polystyrene
ABS: Acrylonitrile butadiene styrene

It is evident from table 1.5 that PVC is the most important of the commodity polymers. Also, there are several manufacturers of PVC in India, and its consumption is expected to grow sharply, with increasing use in construction, agricultural, electrical and footwear sectors. Hence, PVC is one of the downstream petrochemicals chosen for detailed study.

The breakup of production and consumption in India of some important synthetic fibres is given in **table 1.6.**

Table 1.6. Production and consumption of important synthetic fibres in 1993-94

(in thousand tonnes)

Fibres	Consumption	Production
AF	90	67.57
NFY	*	37.34
NIY/TC	*	43.43
PFY	*	286.21
PSF	230.06	200.1

* : Under broadbanding
AF: Acrylic fibre
NFY: Nylon filament yarn
NIY/TC: Nylon industrial yarn/tyre cord

It is clear that PSF/PFY are, by far the major products in this sub-group. The number of industries producing these fibres are also much larger compared to the number of manufacturers of the other fibre products. Understandably, PSF/PFY are the more important man-made fibres, and hence have been selected for a detailed study in this report.

The petrochemical plants in operation today offer an interesting field of study as they were built over a long period of over 30 years, employing different technologies which are not necessarily energy optimized. With the exception of a few large players, the industry by and large continues to operate sub-optimal sized plants based on old

technologies and hence does not benefit from recent advances in technology, capital costs and energy saving schemes. Since most of the petrochemical processes are quite energy intensive by their very nature, energy conservation measures will have a significant improvement in the overall energy consumption pattern in the sector.

Most of the petrochemical plants in India have been set up with know how from reputed international technology suppliers which were state-of-the-art at the time of project conceptualisation. However the process technology in this area is changing rapidly, with the result that there is scope to make drastic improvements in energy consumption by introducing new energy-saving technologies in plants set up only a few years back. Although most of the plants have an energy management cell and carry out continuous improvements in operating and maintenance practices, few plants have gone for major process improvements due to the financial risks involved in such ventures. It is felt that providing financial assistance may motivate/encourage the enterprises in implementing such major energy saving schemes.

1.4 Environmental pollution control

According to the information available with Central Pollution Control Board (CPCB), all the petrochemical plants have installed pollution control measures. However there may be a possibility to install cleaner technologies in some of the processes which would recover chemicals now vented to the atmosphere. In the older plants, there may be scope to further improve the efficiency of the water treatment plants. Ambient air monitoring on a regular basis, in plants where it is not done, would lead to a greater awareness of pollution control among the operating staff of the plants.

CHAPTER 2

Polyvinyl Chloride (PVC)

2.1 Sector profile

PVC is one of the most important plastics, and has the single largest consumption among polymers in India. PVC is widely used in agricultural sector, for low cost housing and for making pipes, drains, elbows and tanks.

The industry has been growing at a brisk pace and the production has recorded a compounded annual growth rate of 31.7 %, from 147,000 MT in 1990-91 to 442,000 MT in 1994-95. The margins have been squeezed recently, because of steep increase in international prices of both the raw materials: Ethylene and Ethylene Di-chloride (EDC). The growth in the increase in installed capacity and production of PVC over the last five years is shown **figure 2.1**.

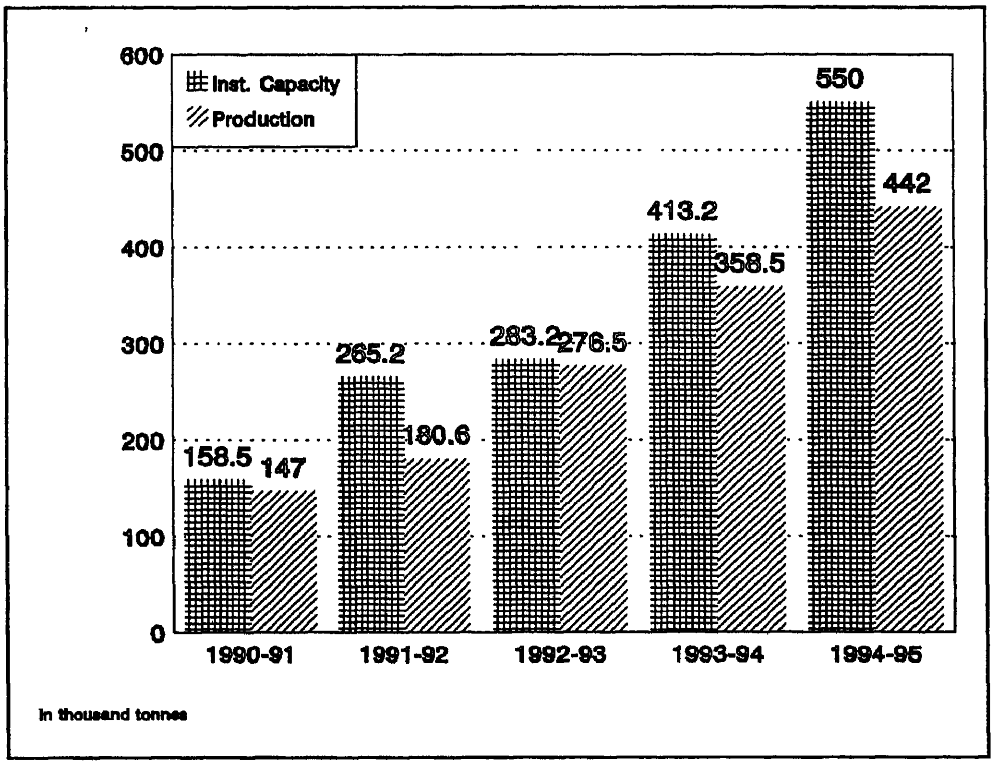


Figure 2.1: Installed capacities and production of PVC in India (Source : Annual Reports, Ministry of Chemicals and Fertilizers)

The installed capacities of the major PVC plants in India in 1993-94 and their year of commissioning are given in **table 2.1**. Calico's PVC plant in Bombay is not shown in the

table since it is not in operation. The private sector is the leader in the production of PVC in India. There is only one company manufacturing PVC in the public sector and almost 86% of the total installed capacity is presently in the private sector. There are no co-operatives in this sector. With the opening up of the economy and delicensing if this sector, major players like IPCL and Reliance are going in for large scale increase in their capacities. More details of individual plants are given in section 2.1.1.

Table 2.1. PVC manufacturers in India

S. No.	Manufacturer	Location	Installed Capacity (TPA)	Year
1.	D.C.M. Shriram Consolidated Ltd.	Kota, Rajasthan	33,000	1964
2.	Chemicals & Plastics India Ltd. (Chemplast)	Mettur, Tamil Nadu	48,000 (exp. planned by 20,000 tonnes)	1967
3.	National Organic Chemical Industries Ltd. (Nocil)	Bombay, Maharashtra	21,500	1968
4.	D.C.W. Ltd.	Tuticorin, Tamil Nadu	42,000 (exp. to 60,000 TPA)	1972
5.	Indian Petrochemicals Corpn. Ltd. (IPCL)	Vadodara, Gujarat	55,000 (exp. 150,000 TPA)	1984
6.	Reliance Industries Ltd.	Hazira, Gujarat	100,000 (exp. 300,000 TPA)	1991
7.	Finolex Industries Ltd.	Ratnagiri, Maharashtra	100,000 (exp. planned by 80,000)	1993 Licensor: Vinnolit Engg: UDHE
		Total	399,500	

Source : CMIE - Market and Market Shares, February 1995 and RIL Annual Report

2.1.1 Status of the industry

The major manufacturers of PVC and their short profile is given below.

i) DCM Shriram Consolidated Limited, Kota

The plant was commissioned in 1964 with Shinetsu technology and vinyl chloride was produced though acetylene route. Acetylene was produced through calcium carbide while hydrochloric acid was obtained from excess chlorine produced in their chloralkali plant. In view of the high cost of production of VCM through this route, they are planning to expand their capacity from 33,000 TPA to 45,000 TPA through EDC cracking.

ii) National Organic Chemical Industries Limited, Thane

The first VCM plant based on petro ethylene was established by NOCIL and commissioned in 1968. The plant is using BASF technology and has an installed capacity of 21,500 TPA. A substantial expansion and modernisation of the Thane petrochemical complex is planned.

iii) The Chemicals and Plastic India, Tamil Nadu

PVC plant was commissioned in 1967 and the plant originally based on alcohol which was available in a large quantity at a low price. Later, the irregular availability as well as the increased cost of alcohol made the plant economically non-viable and they discontinued this route and started manufacturing with imported ethylene dichloride using B F Goodrich technology. The plant capacity is presently under expansion to 60,000 TPA.

iv) D.C.W. Ltd., Tamil Nadu (Earlier Plastic Resins and Chemicals Ltd.)

This plant adopted a technology based on flame cracking of naphtha from Kureha. The plant utilizes the chlorine produced from caustic soda plant and light naphtha from refinery. The capital cost is also relatively low when compared to ethylene route. However, with increased price of naphtha, power, and other technical reasons, this route has become no more economical and the plant was shut down during 1978 to 1983. The production of PVC resumed again with imported VCM, in 1983.

v) Indian Petrochemicals Chemicals Ltd, Vadodara

IPCL is the only public sector undertaking in this sector and was incorporated in 1969. The VCM and PVC plants were commissioned in 1984. The raw material, ethylene is obtained from naphtha cracker while the chlorine is supplied from the neighborhood chlor

alkali plant. The technology licensor for the PVC plant is BF Goodrich and it is based on balanced ethylene chlorination process. The present installed capacity is 55,000 TPA which is planned to be enhanced by addition of a new polymerisation reactor.

The first phase of the Gandhar gas cracker complex of IPCL, targeted for completion by mid-1996 consists of a 1.7 lakh TPA VMC plant and 1.5 lakh TPA PVC plant.

vi) Reliance Industries Ltd., Hazira

Reliance PVC plant at Hazira, based on B.F. Goodrich technology (presently, Geon Company, U.S.A.) is the largest PVC plant in India and achieved a production of 170,000 MT in 1993-94. During 1994-95, production increased by 10% over previous year to reach 187,000 MT. It had expanded its installed capacity from 100,000 MTPA to 135,000 MTPA in 1994-95 through a process of expansion and debottlenecking. Reliance has undertaken a major expansion programme to further increase its capacity to a level of 300,000 TPA, which is expected to be completed next year.

2.1.2 Status of manufacturing technology

There are four major methods of producing PVC:

- Suspension Polymerisation
- Bulk Polymerisation
- Emulsion Polymerisation
- Solution Polymerisation

Suspension polymerisation of Vinyl Chloride is by far the most important technique, employed worldwide, and accounts for about 80% of total PVC production in the world. This is followed by emulsion process with a production capacity of about 10% and bulk process around 8-10%. A small quantity of PVC is also produced by solution polymerisation technique.

Emulsion polymerisation has limitations in terms of product grades and is used only when PVC is required as latex or paste in end use application. Bulk polymerisation, the latest of the four processes has recently become attractive due to low investment and operating costs. Polymerisation is carried out under anhydrous conditions without water and dispersion medium. This eliminates centrifugation and drying steps of suspension polymerisation.

Since presently the suspension process is the major process employed for PVC manufacture in India, this is described in more detail below.

Description of the Suspension PVC Process

The basic raw materials for production of PVC is vinyl chloride which is manufactured by the process shown in **figure 2.2**. A simplified flow scheme of the suspension polymerisation process for manufacture of PVC is shown in **figure 2.3.**

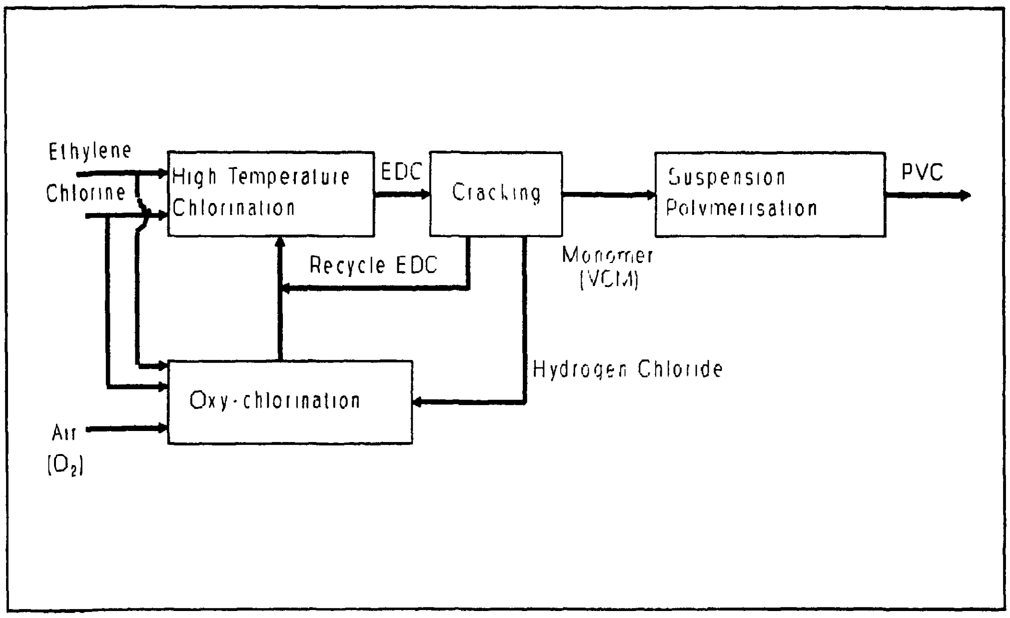


Figure 2.2 : Production of VCM from ethylene and chlorine

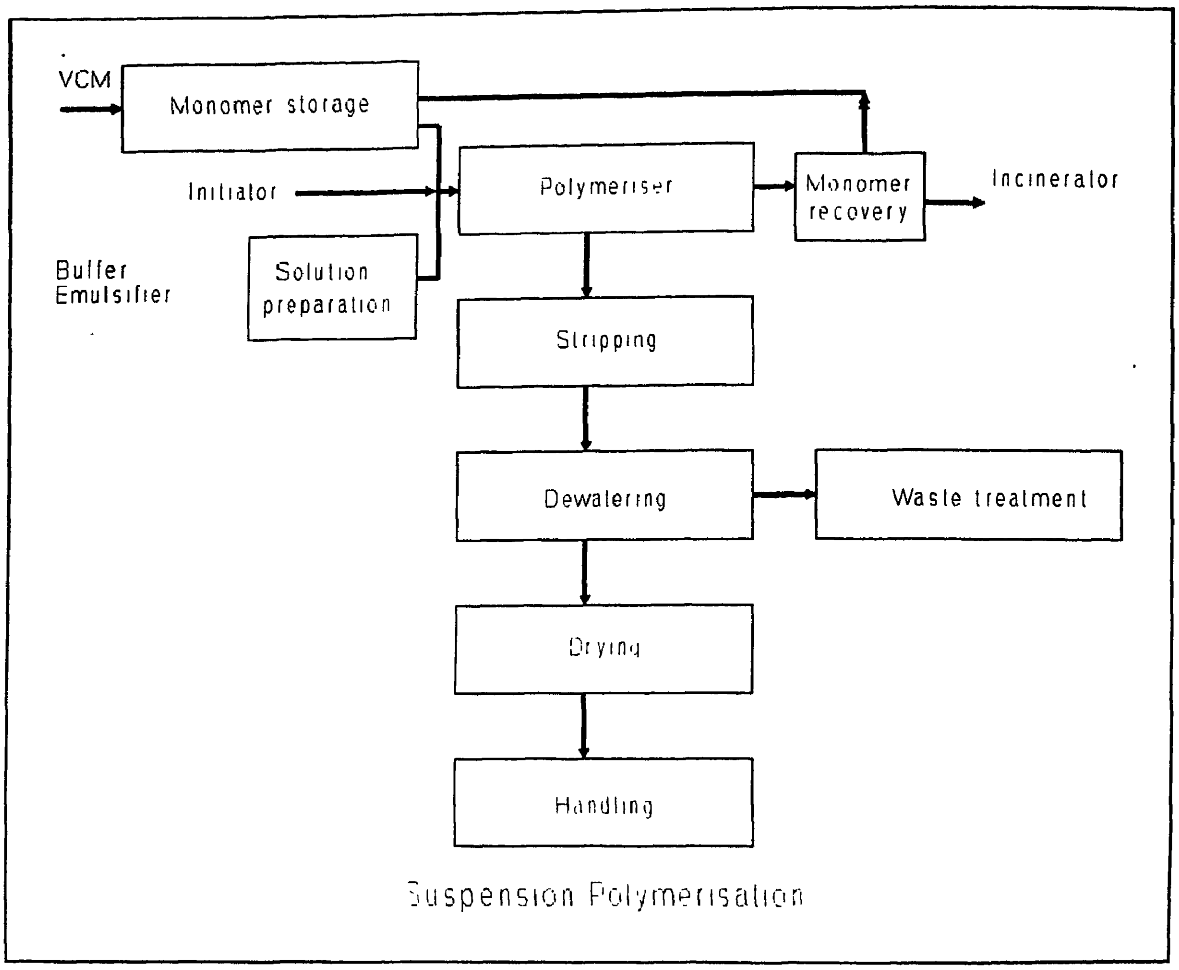


Figure 2.3 : Production of PVC from VMC by suspension process

The PVC suspension process consists of the following operating steps:

a) Catalyst + Chemicals preparation and charging
b) Polymerisation
c) Slurry degassing & stripping
d) Resin drying
e) Monomer recovery
f) Waste water treatment

Preparation Step

a) **Raw Material Handling and Storage**. The unit consists of the facilities for handling of Vinyl Chloride, hot and cold demineralized water, make up and storage of emulsifiers, buffer solution, and catalysts.

b) **Vinyl Chloride**. Fresh Vinyl Chloride is transferred from the monomer storage area as required and stored in a day tank or directly charged to reactor. The charging pumps charge the fresh and recovered monomer to the polymerizer.

c) **Cold Demineralized Water**. The cold demineralized water is stored in an atmospheric tank. This cold demineralized water is used for seal flushing, line flushings, entrainment separator spray and poly injection. The charge pumps are designed for handling both cold and hot demineralized water.

d) **Hot Demineralized Water**. Cold demineralized water is heated by steam and stored in an atmospheric tank. This hot demineralized water is used for polymer charging. Charging hot water minimizes temperature adjustments in the reactor prior to initiation.

e) **Catalysts**. Catalysts are received from the manufacturer in containers, and depending on type, must be kept below -15°C in a refrigerated storage, remote from the process area. This catalyst is used to prepare a dilute non-hazardous solution which is stored at 5°C in the process area. Catalyst solution is pumped to the reactors to initiate the reaction from a weigh tank.

f) **Emulsifiers and Buffers**. Emulsifiers and buffers are received in bags. Facilities are provided for preparing solution. Emulsifiers and buffers are charged to the reactor through small weigh tanks.

g) **Shortstop solution**. Shortstop is received in drums. Shortstop solution is prepared and stored in the shortstop tank. The solution is pumped into the reactors at the end of each reaction cycle to stop polymerisation at the end of the desired conversion for each polymerisation batch.

Polymerisation

Demineralized water, VCM, emulsifiers, buffer and catalyst(s) are added in the specified amounts and sequence. Suspension polymerisation is conducted by dispersing the monomer in the water phase by agitation. The polymerization reaction is highly exothermic in nature producing 360 KCal per Kg of VCM polymerized. To maintain the reaction temperature this reaction heat is removed by either use of cooling and/or chilled water in reactor jackets and consequently additional heat transfer area may be provided by use of reflux condensers or internal baffles, depending on each licensor technology.

Controlled addition of catalyst leads to controlling the rate of reaction and hence rate of heat removal. The heat released during the polymerisation is measured and from this figure, the percent conversion of monomer to polymer is calculated. When the desired conversion is achieved, shortstop is injected to terminate the reaction. The charge is transferred to the stripping column feed tank for recovery of a portion of the unreacted monomers. The recovered monomer is returned to the recovered VCM tanks as recycle step. A system is provided to prepare and apply a coating to the interior surfaces of the reactor between charges to prevent build up of polymer during the next reaction cycle. Small amount of build-up accumulated over approximately 1000 charges is removed with an automatically controlled high pressure water cleaning system.

Slurry Stripping and Blending

The resin slurry is fed continuously from the feed tank to the stripping column, the slurry entering the top of the column counter current to the steam feed. The overheads are sent to a condenser and a condensate receiver from which the condensate is routed to a waste water system and the vinyl chloride gas is sent to VCM recovery tank. The stripped slurry from the bottom of the column is transferred to blend tanks, normally containing a residual VCM concentration of less than 10 ppm depending on resin type. From these tanks, the slurry is fed to a centrifuge.

Waste water from various process sources is accumulated in a storage tank and from there sent to a small column where it is steam stripped to remove Vinyl Chloride prior to sewer disposal. The recovered VCM is sent back to the recovered VCM tank for reuse.

Resin Drying

The polymer slurry particles formed (approximately 140 micron size) are large enough to allow centrifugal separation in a continuous solid bowl centrifuge before drying. The additive agents leave the system with the water. The dewatered slurry is fed to the rotary dryer by means of a wet cake conveyor.

The wet cake is dried by hot air and pulled through the rotary dryer together with the air by the main exhaust blower. Dried resin is separated from the air by the primary cyclone and wet scrubber. Large resin particles collected by the primary cyclone are passed over screen to remove any large particles. Resin is conveyed to the silos by the conveying system. Any fine resin particles carried by the air stream are scrubbed in the secondary collector. Most of the scrubber outlet solution is transferred back to the blend tanks.

Product Storage and Bagging

Product from check silos is transferred to storage silos by pneumatic conveying. From storage silos it is transferred to bagging silo by pneumatic conveying and from there it goes for bagging.

2.1.3 Technology status of Indian PVC plants

With exception of Finolex and Reliance PVC plants, all the other plant capacities installed in India are rather too small compared to international standards. Although, the demand for PVC is increasing steadily, growth rate could not be matched. One of the reasons for this is the lack of raw material availability for the production of PVC which requires either acetylene or ethylene. In case of acetylene, the cost of production being high through calcium carbide route, this technology could not be adopted any longer for building new plants. In case of ethylene route, the availability of ethylene is linked up with Naphtha or gas cracker. At present, the ethylene produced from cracker units are tied up with committed down stream users and installing a new cracker plant means establishing a big petrochemical complex requiring huge investment.

Some salient points about the PVC technology in Indian plants are given below.

a) Scale of Operation

Scale of operation of Indian PVC industry is quite small compared to international standards. Government of India have recommended a capacity of 100,000 MTA as the minimum economic size (MES) capacity for PVC plants. It can be seen from table 2.1 that most of the PVC plants in India do not meet the above requirement.

b) Reactor Size

Reactor of 200 m^3 volume is in commercial use in international scene. Compared to this, Indian plants are using small size reactors. Even IPCL plant is having a reactor size of 70 m^3. Most other plants are having much smaller sized reactors and in some plants reactor size as low as 8 m^3 volume are in use.

c) Clean Reactor Technology

This is an important development in the PVC technology. This completely eliminates or reduces drastically the requirement of opening of the reactors for cleaning the walls. This is achieved by means of using special coating given at the start of each batch of polymerization and/or by use of pressure water jet for cleaning. Reliance, IPCL and Shriram Fertilizers & Chemicals plants are designed with this technology. NOCIL has incorporated this technology from B.F. Goodrich in 1986. DCW has acquired the know-how from AUTOCHEM in 1987 for preventing build-up in the reactors. Details of these system are however not available. It appears that other PVC producers in India do not have this technology and require frequent opening of the reactors and therefore operator's exposure to VCM is on the higher side.

2.2 Energy profile

PVC is quite a energy intensive process and the net specific energy requirement for manufacture of PVC from vinyl chloride monomer (VCM) in Indian plants is about 2445 Mcal/ton*. This is excluding the energy consumption of preceding chemical operations like production of the monomer from ethylene and chlorine which consumes about three times the energy required for production of PVC from the monomer. For a production of

*Average of four plants - NOCIL, IPCL, Reliance and DCW in 1993-94, which accounted for about 77% of the total production of PVC in India.

442,000 MT in 1994-95 the total net energy consumption in the PVC sector works out to be about 1.1 x 10^6 Gcals. The share of the different forms of energy in PVC manufacture is shown in **figure 2.4**.

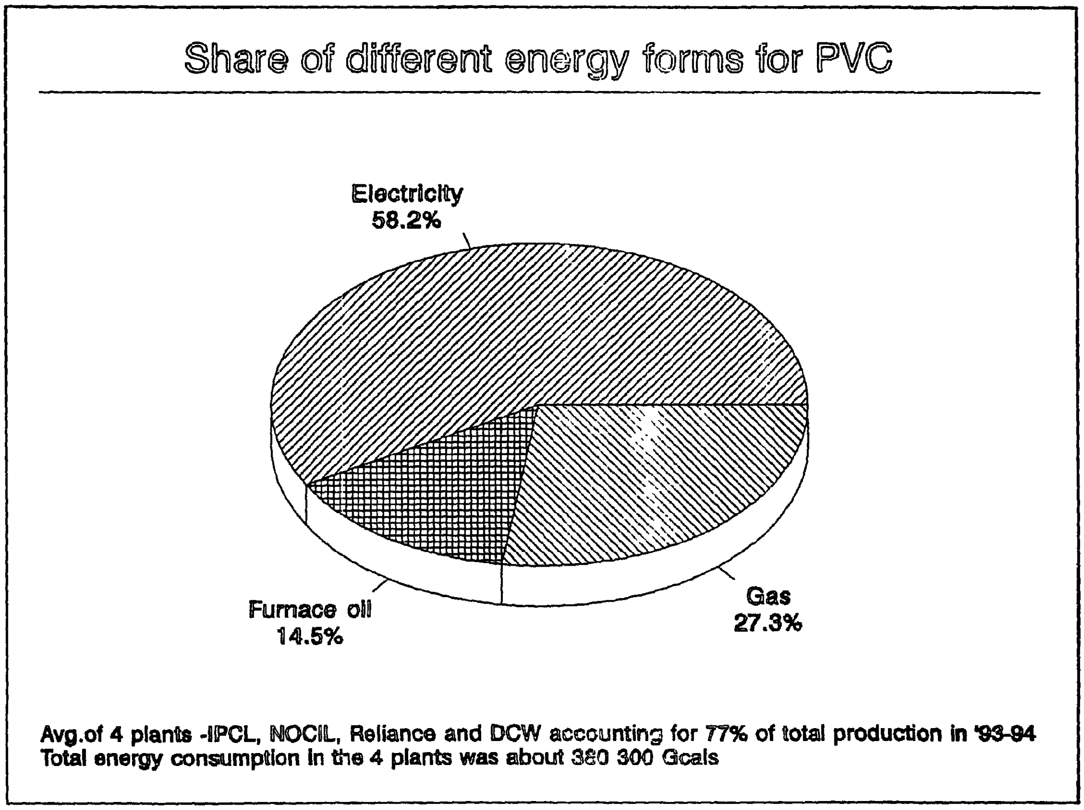


Figure 2.4: Share of different energy forms in the PVC sector

The specific energy consumption norm for the suspension process and the actual specific energy consumption figures achieved by some major PVC producers in India is given in **table 2.2**. Detailed plant data is given in Annexure.

Table 2.2. Specific energy consumption for PVC manufacture by suspension process*

(1993-94)

S.No	Energy form	Unit	Normative value	Actual IPCL#	Actual DCW#	Actual NOCIL#	Actual Reliance#
1.	Electricity	KWH	225	205	402	563.5	454
2.	Steam						
	MP	MT	0.996			0.88	
	LP	MT	0.265			0.63	
	Total	MT	1.261	1.1		1.51	
3.	Furnace oil	KL			0.06		
6.	Gas	SM^3					126
7.	Total specific energy	Mcal/MT	1835	1633	1935	3214	2696

#Source :
Questionnaire - IPCL & NOCIL
Reliance Annual Report 1994-95
DCW Annual Report 1993-94

*Basis:
1 kWh = 3440 Mcal
1 SM^3gas = 9000 kcal
1 ton coal = 4000 Mcal
Steam:coal = 4.75:1

Typical consumption of raw material, catalyst and chemicals for the suspension process, are given in **table 2.3.**

Table 2.3. Typical raw material, catalyst & chemicals consumption in PVC suspension process

Sl.No	Items	Unit	Consumption norm per MT of PVC
1.	VCM	MT	1.014*
2.	Catalyst (Bis-2 ethyl hexyl-Peroxydicarbonate)	Kg	1.60
3.	Polyvinyl acetate (72.5% hydrolysed)	Kg	0.96
4.	Polyvinyl acetate (88% hydrolysed)	Kg	0.18
5.	Cellulose	Kg	0.058

* Recently, licensor like BFG & UHDE Guarantee a VCM consumption of 1.002 T/T of PVC.

2.3 Energy conservation opportunities

The major developments which could lead to significant reduction in the energy consumption levels in the PVC are discussed below.

a) Higher productivity reactor technology

Newly developed design principles for the reactor has lead to higher productivity per cubic meter of reactor volume because of a higher overall heat-transfer coefficient. The overall heat transfer coefficient is increased from about 300 kcal/m^2/hour/ °C to over 1200 kcal/m^2/hour/ °C. The heat transfer area is increased by about 50 percent because of "corrugated-iron" like surfaces of the walls. There is no need for the chilled water and the process would use cooling water at 30 °C. Reflux condensers will also not be required.

Typical saving due to installation of high productivity reactor in a 50,000 TPA PVC plant is detailed below.

Chilled water consumption norm at 4 °C	=	22 m^3/t
Annual production capacity	=	50,000 t
Hence, annual chilled water consumption	=	1,100,000 m^3

Annual saving due to elimination of chilled water is about Rs 110 lakhs (Assuming cost of chilled water to be Rs 10/m^3).

Investment for this changes, however, will be quite substantial and the same could be obtained only from major technology suppliers.

b) Use of computer control resulting in greater safety and higher productivity. In the latest control systems like the one licensed by HOECHST AG, temperature is controlled by the use of microprocessor for each reactor. Hence the extensive decentralisation results in better reliability of the entire process than it would be if the computer functions were centralised. Much precise control of the internal reactor temperature can be achieved (upto $\pm$ 0.1 deg. C) because the control system is able to compute all the variations in parameters that can disturb precise temperature control and then take that information into consideration in determining coolant inlet temperatures. Also, the continuous information about and computation of the temporal course of the reaction's heat flow, the actual heat-transfer coefficient, and the conversion rate make possible the timely recognition of abnormalities in the polymerisation process, thus increasing the safety of the operation. The extrapolation of the temporal course of the reaction's heat combine with the ability to

predict the heat transfer coefficient - 1 hour in advance allows for timely determination of the minimum required coolant supply temperature.

c) Development of clean reactor technology where cleaning of the reactor is either not required at all or cleaning is required after a long time. During the discharge cycle the reactor wall is flushed with water automatically by a flushing devise installed at the top of the reactor. After this, the reactor wall is coated by a special wall-coating program before a new batch is started. After the completion of production of a particular PVC type, general cleaning of the reactor takes place automatically by means of high pressure water.

d) Improved stripping (degassing) process

The PVC slurry discharged from the polymerisation reactors into the intermediate tank contains about 10 percent of unreacted VCM. The basic principles of two energy saving degassing technologies are shown in **figures 2.5 & 2.6**.

In the column version, the partially degassed slurry from the intermediate tank is pumped to the slurry tank via spray nozzles, thus degassing further VCM. The slurry is preheated before being fed to the degassing column feed vessel. From there the slurry is continuously pumped to the top of the degassing column, where the suspension is degassed to VCM values below 10 ppm. The column is heated to temperatures of about 100 to 110 °C at the bottom and 95 to 105 °C at the top by introducing stripping steam at the bottom, and is operated at close to atmospheric pressure. The degassed slurry after heat exchange with the feed to the degassing column feed vessel, is stored in the centrifuge feed tank.

In the multicell version, the degassing is performed at reduced temperature under vacuum and hence is particularly suitable for heat sensitive products. Similar VCM content as that achieved by the column version is also achieved in this version.

e) Developments in new dryer systems such as flash-fluid dryer and Hoechst's new cyclone dryer

An improvement over the rotary dryer is the flash fluid and cyclone dryers. In flash-fluid, first the wet power is subjected to flash drying where the PVC comes in contact with hot air which pneumatically conveys it to separation cyclone. Here the external moisture is removed from the PVC particles and then for removing the inherent moisture, the powder is discharged to a plug flow fluidization dryer. Typically the moisture content is brought down from 30% to 2% in 1st stage flash and from 2% to 0.1% in 2nd stage fluid drier.

A more recently developed cyclone dryer by M/s. Hoechst makes use of cyclones having internal trays. The cyclone dryer uses the principle of a "hurricane flow" of gas surrounded by a shield of stainless steel and divided into four or five vertical chambers. The residence time of the product is about 20 min. Hot air conveys the PVC powder to the cyclone dryer and at the outlet, fines are separated from the air through separate cyclone and bag filters. The main advantage of this dryer design is that the residence time of the PVC particles in the dryer will be dependent on the particle size. Larger particles will have a longer residence time in the dryer and likewise smaller particles will have shorter residence time, thus ensuring no overheating of smaller particles. In terms of thermal efficiency, versatility to handle grade changes with minimum down time and ease of maintenance, flash fluid and cyclone dryers are reported to be superior than conventional rotary dryers. The Hoechst cyclone dryer consumes much less energy due to operation close to the dew point. Another advantage of this dryer system is that no contamination occurs by changing PVC type from a high K value to a low K value. Products with precisely defined water content can be obtained.

f) Recovery of steam condensate

In most of the existing PVC plants, the steam condensate is being drained out. The sensible heat lost in the condensate is quite high and can be utilised by having a condensate recovery system. The Reliance PVC plant has achieved a saving of 1.8 TPH of DM water and 0.13 MM kCal/hr of energy savings due to blowdown recovery.

g) Reorientation of steam traps to save steam

There are a large number of stream traps of various sizes and pressures used in the PVC plant. Most of the plants employing disc type steam traps along with a small percentage of basket types. The actual loss during normal operation is much higher than 5-10% specified by the manufacturer and in the range of 20-30% which is of the order of 4 kg of steam per hour per steam trap. Hence a large number of stream traps could be eliminated and steam trap model changed to bi-metallic type which does not cause the steam leakage. In a large petrochemical complex in Japan, which had 5526 steam traps, 22 ton/hour of steam was saved by reorientation of steam traps. Reliance has also achieved substantial energy saving by audit of the steam traps in the PVC plant.

2.4 Environmental aspects

The discovery in 1973 that the exposure to Vinyl Chloride resulted in increased incidence of a form of Liver cancer (angiosarcoma) resulted in fundamental changes in the PVC

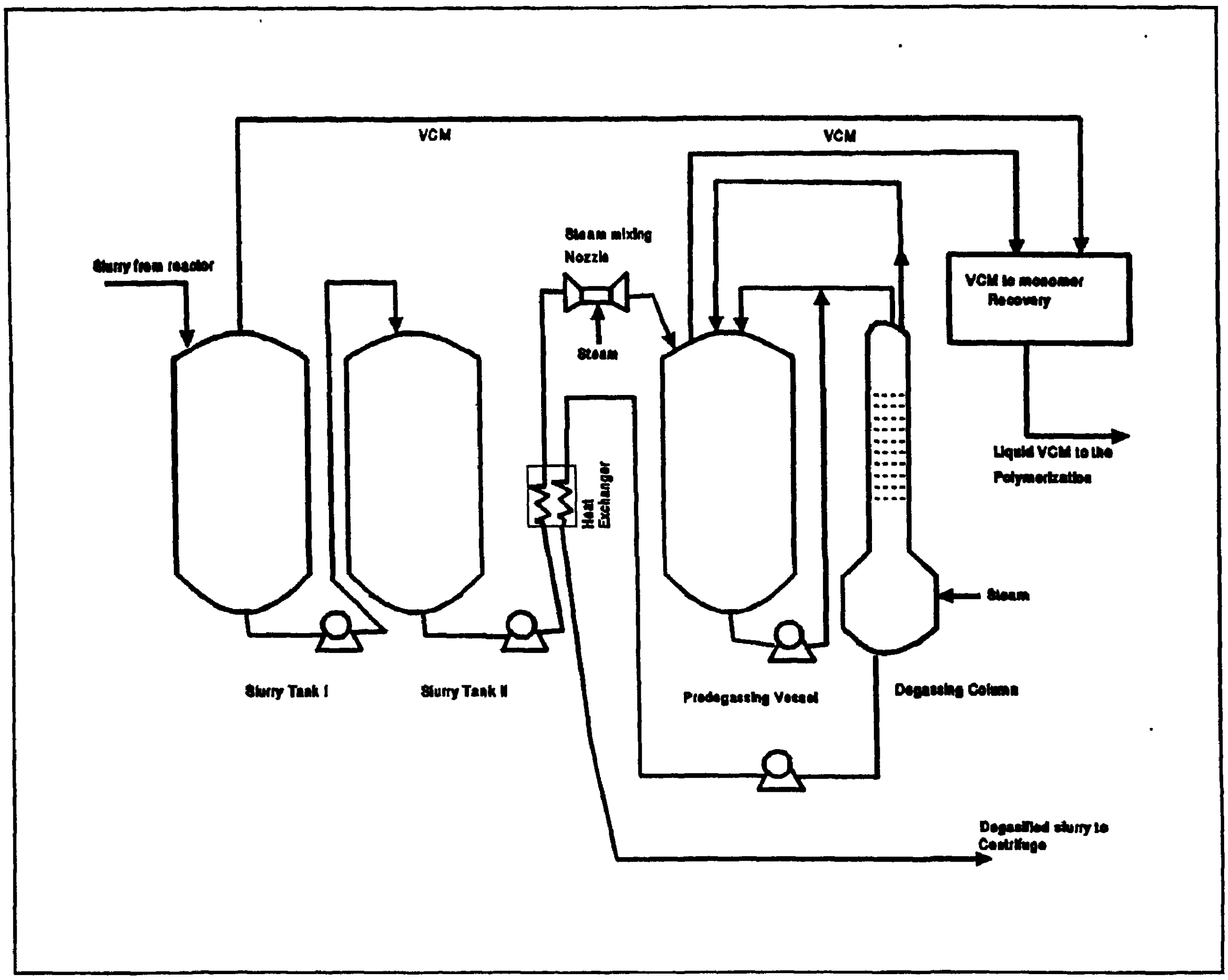


Fig. 2.5 : Schematic flowsheet of Hoechst PVC-degassing section/column versions.

industry. Following this discovery OSHA (Occupational Safety and Health Administration, USA) issued regulations in 1974 limiting employer exposure. In 1976, EPA (Environmental Protection Agency, USA) issued an emission standard, limiting the VCM concentration in the resin slurry, reactor opening emissions and other plant VCM emissions. There has been major technological improvements in the 1970's like stripping technology, close reactor technology, vent emission controls etc., to comply with OSHA and EPA regulations. Most of the old generation plants in India are yet to adapt these advanced environmental techniques.

The Minimal National Standards (MINAS) for petrochemical industries (basic and intermediate products) is given in **table 2.4**. However the different state pollution control boards follow different standards, which are in slight variance from the MINAS standard.

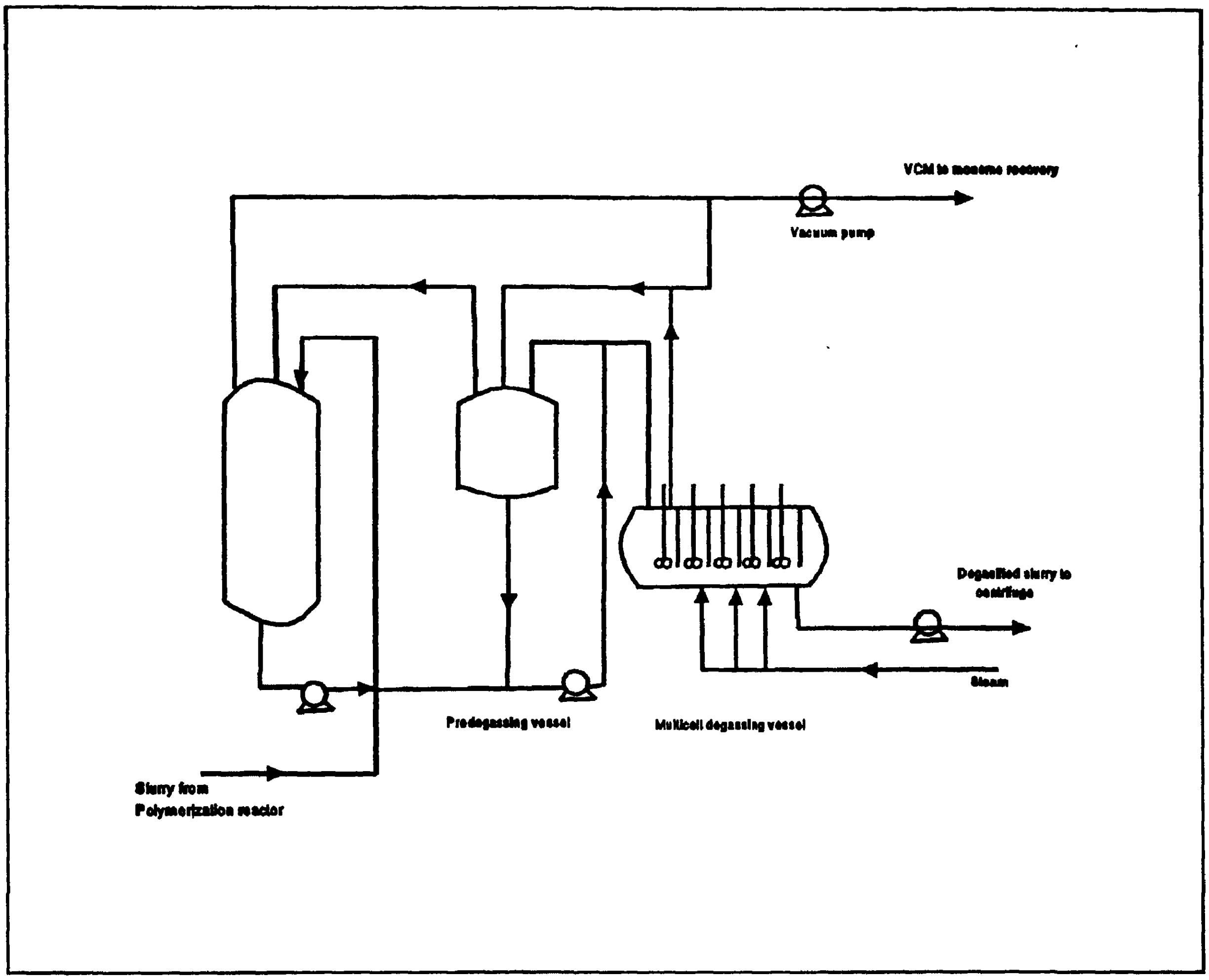


Fig. 2.6 : Schematic flowsheet of a Hoechst PVC degassing (multicell version)

Table 2.4. MINAS for petrochemical industries

Parameter	Limits not to be exceeded
pH	6.5-8.5
BOD_5 20°C, mg/l	50
COD, mg/l	250
Phenol, mg/l	5
Sulphide as S, mg/l	2
Cynide as CN, mg/l	0.2
Fluoride as F, mg/l	15
Hexavalent chromium Cr, mg/l	0.1
Total chromium as Cr, mg/l	2
Total suspended solids, mg/l	100

The petrochemical complexes usually have a separate facility for the treatment of different effluent streams from VC/PVC plant. The high volatile chlorinated hydrocarbon bearing

waste stream is segregated and volatile pollutants are stripped off in a flash aeration tank. The effluent from the flash aerator basin, and other effluents are mixed and equalised in surge ponds. The equalised effluent is then treated in flash mixer for hydrolysis of 2 chloroethanol and chiral to render them biodegradable by dosing 10% FeSO4 and 5% NaOH solution in the required doses. The basic treatment scheme is shown in **Figure 2.7**.

a) *Monomer Recovery*

Unreacted monomer removed from the polymerizers, the feed tank, and the entrainment separator is compressed and then condensed in a water cooled condenser. Most of the recovery of unreacted monomer is done downstream of the polymerisation. Monomer removed by the stripping column is also compressed and condensed. All recovered monomer is finally recycled for polymerisation.

Inert gas accumulated in the monomer recovery system is vented to the atmosphere through an absorber-stripper system which removes Vinyl Chloride and returns it to the recovery system for reuse or is sent for disposal in incinerator located in VCM plant, depending upon the quantity and composition of the vent gas.

Earlier gases vented to atmosphere were rich in VCM content. With the stripping of vent gas, VCM content presently is kept within 10 ppm max. (EPA regulations). This has also improved the VCM specific consumption for producing PVC.

Membrane process for vinyl chloride recovery

The membrane process for eliminating vinyl chloride from VOC-laden air streams is the latest process for treating exhaust gases from PVC plants. It can attain recovery efficiencies from 90% to 99.9% and the VOC is recovered for reuse without a steam or inert gas regeneration step.

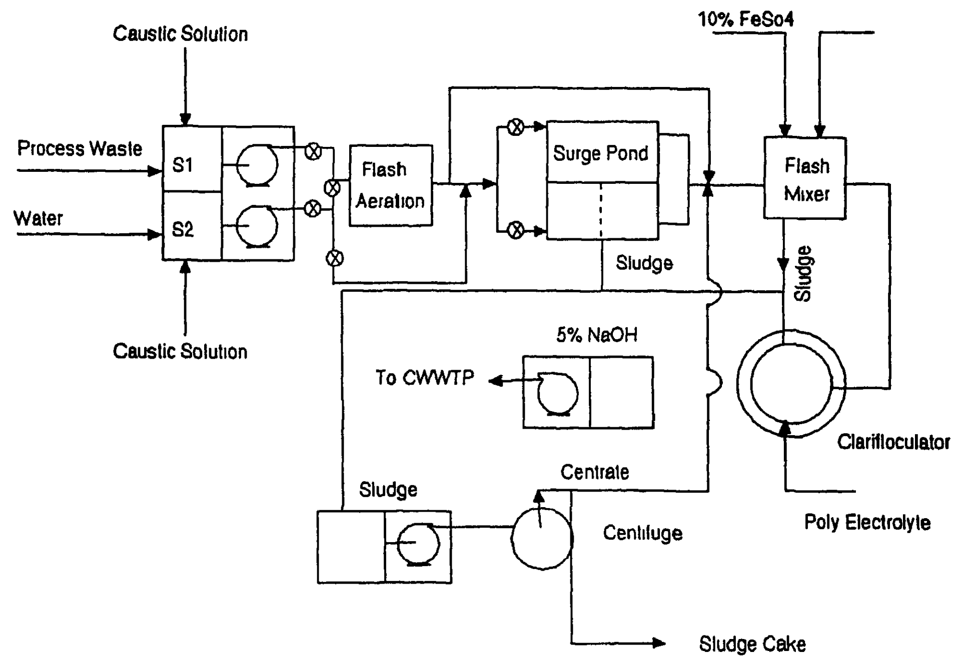


Fig. 2.7 : ISBL Treatment at VC/PVC

A flow scheme of the process is shown in **figure 2.8**. The process consists of compression, condensation and membrane vapour separation. The membrane separation is based on organic selective membranes that are 10 to 100 times more permeable to the organic compound than air. During VOC recovery, the air stream containing organic vapour is compressed. The compressed mixture is sent to the condenser. Some of the organic vapour condenses and is sent to a storage tank for reuse. The non-condensed portion of the mixture passes into the membrane unit and across the surface of an organic-selective membrane. The membrane separates the gas into two streams: a VOC-enriched permeate stream and a VOC-depleted air stream. The enriched permeate stream is recycled to the inlet of the compressor. The VOC-depleted air stream is released to the atmosphere. To provide the driving force for permeation, a lower vapour pressure is maintained on the permeate side of the membrane than on the feed side.

The system cost varies according to the design and capacity. Payback (from

resource recovery) on capital investment be as low as six months. There are twenty-three commercial installations of this technology.

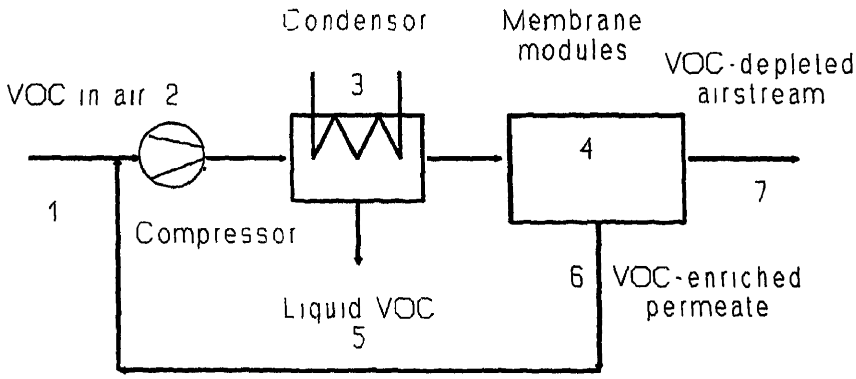


Fig. 2.8 : Membrane process for Vinyl chloride recovery.

Employment of this technology will also reduce the VCM concentration in the working area by reducing the exposure level. This will also help in reducing the losses of VCM and there will be saving in raw material cost.

b) Employing Clean Reactor Technology

In the past, cleaning of reactor wall was being done manually by opening the reactor. Development of methods for pre-coating the reactor wall to avoid or reduce scaling, methods to automatically clean the reactor by high pressure water jets without opening the reactor etc. has resulted in significant reduction in exposure to VCM. This development, though took place primarily for reducing VCM exposure, has also helped to increase productivity by improving the reactor availability.

It may not be possible to employ clean reactor technology in some existing reactors. However, in such cases, provision for cleaning the reactor by high pressure water jet should be provided to avoid entry of men into the reactor for cleaning.

c) Containment of VCM and Monitoring

Containment of VCM and its monitoring is very important in PVC plant from safety and health point of view. Containment of VCM can be effected by the above measures along with certain good engineering practices. These include a complete engineering review of plant to see how VCM leakages, spillages, etc. can be minimized (for example changing a type of valve with an appropriate one may reduce leakage of VCM). The VCM exposure limit in plant should be as per OSHA regulations.

d) Development of Improved Stripping Technology to reduce VCM content in PVC Product

The statutory regulations regarding VCM exposure (OSHA) has been tightened due to its carcinogenic nature. This has resulted in significant developments in degassing and stripping methods and the VCM content in PVC has been reduced to less than 1 ppm. This development also had helped in reducing specific VCM consumption for producing PVC.

In developed countries, PVC used in food packaging contains less than 1 ppm residual VCM so that VCM does not migrate from PVC to food. Glitsch Inc. are the licensor for a new vinyl chloride removal from PVC slurry process, which employs low pressure steam for removing VCM from PVC slurry. The recovered monomer is recycled back to the process.

CHAPTER 3

Polyester - Chips, Yarn & Fibre

3.1 Sector profile

The polyester industry witnessed a phenomenal growth in recent years mainly because of rising prices of cotton and lowering of excise duty on yarn. Polyester fabric has become more affordable for the consumers with the result that there has been a marked shift from cotton to polyester fabrics.

Raw material availability and price has a significant impact on the industry. Due to shortage of paraxylene and resultant shortfall in supply of major raw materials namely DMT and PTA, the prices has been raised a number of times. Margins had been squeezed due to opening up of the market to international players and possibility of reduction in import duties.

Total installed annual capacity of PSF & PFY presently is about 5.33 lakh tonnes. The capacity could even be higher, if manufacturing capacity for other synthetic yarns such as NFY is diverted to PFY as allowed under broad-banding policy. The PSF production has grown at a compounded growth rate of 13% in the past five years and stands at 220,000 MT in 1994-95. The PFY grew at the rate of 12.5% compounded in between the same period and production during 1994-95 was 295,000 MT. The growth in the installed capacity and production of PSF is shown in **figure 3.1**. **Figure 3.2** shows the increase in production of PFY over the last five years. The installed capacities are not reported for PFY in the Annual Plans of the Planning Commission or the Annual Reports of the Ministry of Chemicals and Petrochemicals as NFY, NIY and PFY are categorised under broadbanding. The government has recently liberalized it licensing policy and thus a phenomenal growth is expected in near future.

There are more than 24 companies manufacturing PFY and new players are entering almost every month. Major manufacturers of PFY in India (more than 5% market share) are Reliance, Century Enka, DCL Polyester, Petrofils, Sanghi Polyesters, Raymond Synthetics and J.K. Synthetics.

Presently there are atleast 13 companies producing PSF in India. The major manufacturers of PSF (more than 5% market share) in India are Reliance, JCT, India Polyfibres, J.K. Synthetics, Indian Organic Chemicals, J.K. Corp, Bongaigaon Refinery & Petrochemicals and ICI.

The major manufacturers of PFY and PSF are given in **tables 3.1** and **3.2** respectively. It can be seen that the private sector is the leader in the production of polyester. There is only one company each in the cooperative and joint sector in the

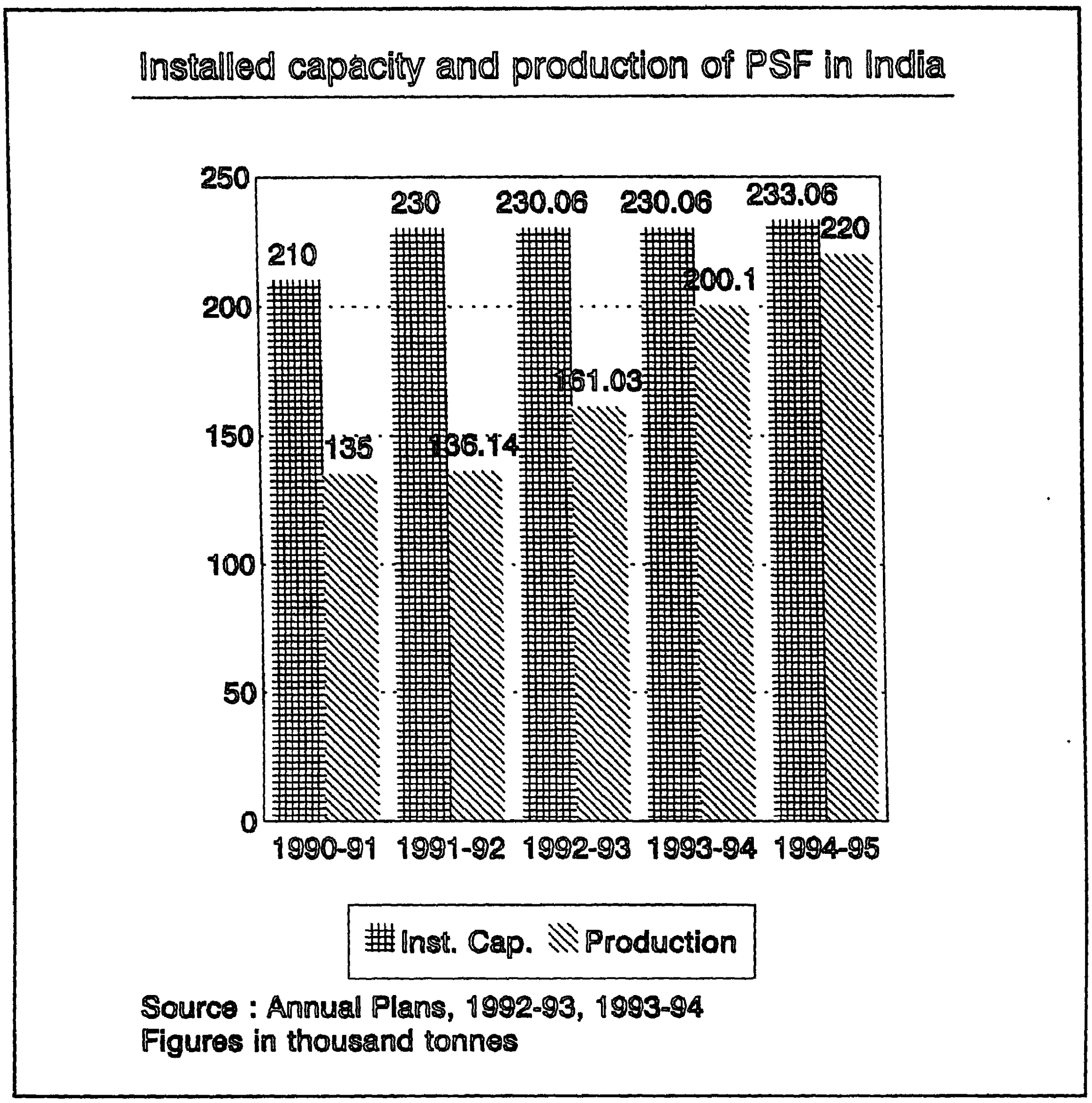


Figure 3.1 : Installed capacity and production of PSF in India

production of PFY and one public sector company in the production of PSF. With delicencing of this sector, the private sector participation is likely to go up further in the near future.

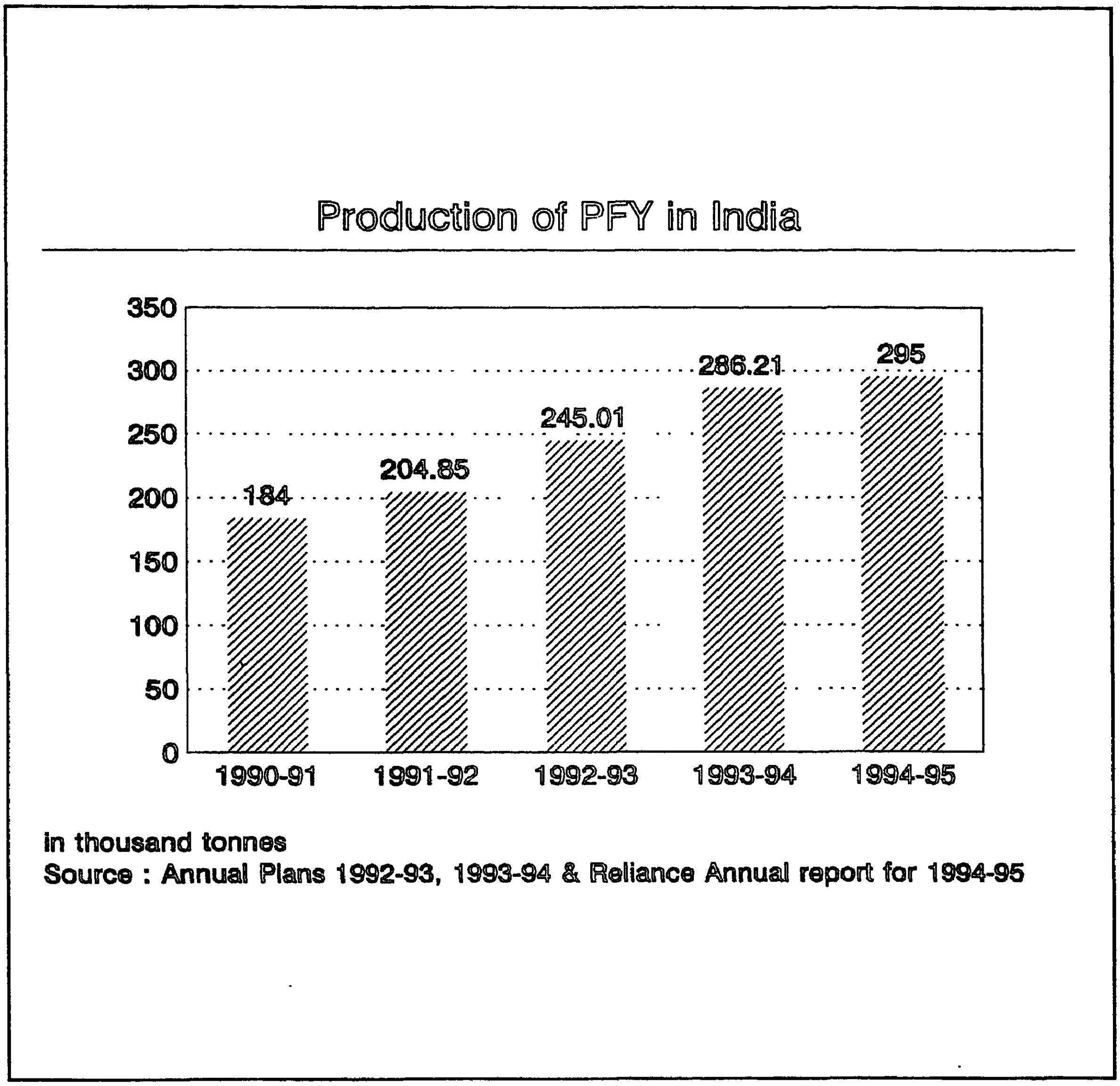


Figure 3.2 : Production of PFY in India

Table 3.1. Major PFY manufacturers in India

S.No.	Name of the Company	Location	Installed Capacity (TPA)	Production 93-94, TPA	Ownership
1.	Reliance Industries Ltd.	Patalganga, Maharashtra	32,300	93,397	Private
2.	Century Enka Ltd.	Bhosari, Maharashtra	31,400	19,740	Private
3.	DCL Polyesters Ltd.	Mouda, Maharashtra	22,000	21,537	Private
4.	Petrofils Co-op Ltd.	Naldhari, Gujarat	N.A.	19,000	Co-operative
5.	Sanghi Polyesters Ltd.	Sanghinagar, A.P.	25,000	19,598	Private
6.	Raymond Synthetics Ltd.	Karchana, U.P.	16,350	16,007	Private
7.	J. K. Synthetics Ltd.	Kota, Rajasthan	10,700	14,817	Private
8.	Parasrampuria Industries Ltd.	Bhiwadi, Rajasthan	18,625	13,589	Private
9.	Haryana Petrochemicals Ltd.	Rewadi, Haryana	2900	8775.55	Private
10.	Baroda Rayon Corpn. Ltd.	Surat, Gujarat	10,777.00	8008.00	Private
11.	J K Corp. Ltd.	Lakshminagar, Orissa	28,000	N.A.	Private
12.	Shree Synthetics Ltd.	Ujjain, Madhya Pradesh	9500	6017.00	Private
13.	Indian Organic Chemicals Ltd.	Madras, Tamil Nadu	9175	5868	Private
14.	J C T Ltd.	Hoshiarpur, Punjab	2000	3633.70	Private
15.	Welspun Polyesters (India) Ltd.	Palghar, Thane, Maharastra Talasari, Thane, Maharastra Silvassa, Dadra & Nagar Haveli, DNH	N.A.	3386.00	Private
16.	Garden Silk Mills Ltd.	Surat, Gujarat	3000	566.97	Private
17.	Nirlon Ltd.	Thane, Maharashtra	3500	3494.50	Private
18.	Ester Industries Ltd.	Nainital, UP	4000	3335	Private
19.	Orkay Industries Ltd.	Raigarh, Maharashtra	8000	7464.93	Private
20.	Prag Bosimi Synthetics ltd.	Darrang, Assam	20,000	1346.38	Joint sector
21.	Garware Nylons Ltd.	Pune, Maharashtra	N.A.	N.A.	Private
22.	Parasrampuria Ind. Ltd.	Dadar & Nagar Haveli, DNH	N.A	1109.63	Private
23.	Welspun Syntex Ltd.	Dadar & Nagar Haveli, DNH	376	323.32	Private
24.	Modipon Ltd.	Meerut, UP	3500	N.A.	Private

N.A: not available

Table 3.2. Major PSF manufacturers in India

S.No.	Company name	Location	Installed Capacity (TPA)	Production 93-94, TPA	Ownership
1	JCT Fibres Ltd.	Hoshiarpur, Punjab	20000	25584.94	Private
2	India Polyfibres Ltd.	Bara Banki, Uttar Pradesh	15000	18309	Private
3	J K Synthetics Ltd.	Kota, Rajasthan	13000	14497	Private
4	Indian Organic Chemicals Ltd.	Madras, Tamil Nadu	34000	14433	Private
5	J K Corp. Ltd	Dhenkanal, Orrissa	N.A	N.A.	Private
6	Bongaigaon Refinery & Petrochemicals Ltd	Bongaigaon, Assam	30000	17227	Public
7	ICI India Ltd.	Thane, Maharashtra	20000	10618	Private
8	Swadeshi Polytex Ltd.	Ghaziabad, Uttar Pradesh	14000	10350	Private
9	Ahmedabad Mfg. & Calico Prtg. Co. Ltd.	Ahmedabad, Gujarat	7968	2552	Private
10	Eastern Spg. Mills & Inds. Ltd.		N.A.	N.A.	Private
11	Kamadgiri Synthetics Ltd.		N.A.	N.A.	Private
12	Malwa Cotton Spg. Mills Ltd.		N.A.	N.A.	Private
13	Reliance Industries Ltd.	Raigarh, Maharastra	45000	76484	Private

N.A.: not available

3.1.1 Status of industry

Some of the major manufacturers of polyester has been chosen for detailed analysis below.

(a) Reliance Industries Limited

Reliance has the largest plant for manufacture of PFY and PSF in the country having started production in 1982. Its current installed capacity of PFY and PSF are 32,300 TPA and 45,000 TPA respectively and enjoys a market share of 30% of PFY market and about 40% of the PSF market. The production and spinning facilities are under further expansion. It has the latest technology of continuous polymerization directly coupled with spinning, supplied by E.I. DuPont, USA. Due to large and economical size of plant and better technology, its product enjoys a good reputation in the market and its financial performance is very encouraging. The plant uses PTA as feedstock which results into economy in cost of production. It has its own facilities of texturizing and weaving and has gone for backward integration, by manufacturing also the raw materials i.e. PTA and MEG. Reliance is setting up a new polyester complex at Hazira of 360,000 TPA capacity including a 160,000 TPA PSF plant. The new plant will be fully automated starting from feeding of raw material to the loading of final products into the trucks. The complex will also house a 120,000 TPA POY plant which will be the largest in the country.

(b) Century Enka Limited

Century Enka is having collaboration with Enka International. It started manufacturing PFY in 1978 with technology from Akzo Nobel, Holland. Its present installed capacity for textile and industrial yarns is 31,400 MT. The production of polyester yarn was 19,740 MT in 1993-94 but. It a conventional batch process but going for substantial expansion in its capacity with modern continuous process and have plans to phase out old and energy inefficient equipment.

(c) DCL Polyesters Limited

DCL Polyester has EMS Inventa, Switzerland technology of continuous and batch process. 85% of total capacity is continuous process and 15% is batch process for specialty yarns. The throughput of yarn was 25,000 tonnes in 1994-95. To reduce dependance to availability of PTA, the company decided to shift to DMT even though it gives a slightly higher production cost. Its installed capacity is being increased from 22,000 tonnes to 1,00,000 tonnes this year.

(d) Petrofils Co-operative Limited

Petrofils, a joint venture of Government of India and Weavers Cooperatives, started manufacturing PFY at Vadodra in 1977, with the conventional spinning plant and technical know-how from M/s J.K. Synthetics. Subsequently they set up a polymerisation plant with technical know-how from Inventa and POY spinning plant with technical know-how from Lurgi. Company's performance is impressive. It has a batch process of considerably large batch size. Its present capacity is 7,000 tonnes. It is going for substantial expansion with modern technology in near future.

New units such as Indian Rayon, Bharat Synthetics, Raasi Synthetics, Khoday Distilleries, have come up with continuous process technology. M/s. Indian Rayon has proposed the same type of combination but having additional facilities for U.D.Y. It has proposed to have Toray technology. Raasi Synthetics has proposed Chemtex collaboration. Bharat Synthetics has proposed Dicier technology. All these plants will have an installed capacity of 15,000 TPA each. Indo Rama Synthetics is planning a capacity of 2.35 lakh tonnes per annum. Sanghi intends to come up with a 35,000 TPA plant. There are many others in the line as well.

3.1.2 Process technology

Till the development of Purified Terephthalic Acid (PTA) in 1963, DMT was used as the only raw material for polyester production. This was due to the fact that terephthalic acid could not be produced with a purity required for fibre production. The crude terephthalic

acid produced was being esterified with methanol to DMT. Since then, share of terephthalic acid for polyester fibre production has increased, and is now over 50% as compared to DMT based polyester fibre production. It is expected to increase further in future.

Out of the two alternative raw materials i.e. DMT and PTA, it is advantageous to use PTA as it gives 15% higher production and requires less investment in capital equipments. The requirement of glycol is also lower. During recent years, almost all new plants worldwide are pursuing the PTA route but due to availability, the use of DMT is still continuing though its percentage share as a feedstock for polyester is declining rapidly.

Manufacturing Process

The manufacturing process of polyester, polymer or chips, is shown in **Figure 3.3**.

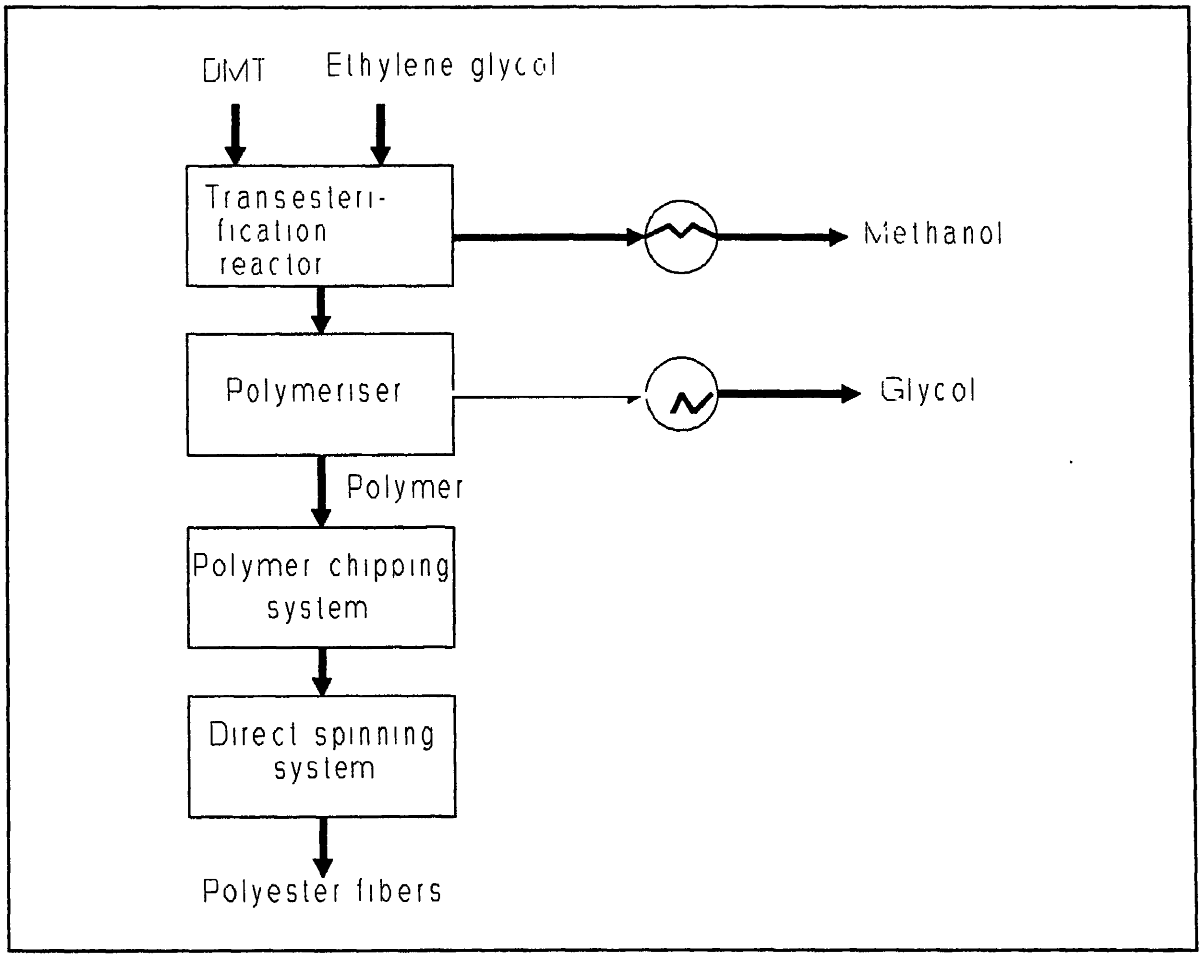


Figure 3.3 : Flowscheme for the manufacture of polyester fibers from DMT

Polyester filament yarns are manufactured either from molten polymer or polyethylene terephthalic acid (PET) chips by melt spinning process. A polyethylene terephthalate

(PET) is made by the condensation of terephthalic acid, or a derivative such as Dimethyl-terephthalate (DMT), with ethylene glycol (EG), followed by polymerisation. The reaction involved is direct esterification in case of PTA and trans-esterification in case of DMT, followed by polycondensation. The reaction is carried out in one or more reactors above atmospheric pressure and at elevated temperature. Excess glycol is used for carrying out the reaction, which is recovered during polycondensation and os reused. Proper control of temperature, pressure, time of reaction and vacuum is necessary for quality control and for this, different designs of reactors and new and better additives and catalysts are used.

The steps involved in the production of polyester are as follows:

(a) Direct Esterification (from PTA)

The reaction is normally carried out above the atmospheric pressure without a catalyst and at a temperature of 220-260°C or Trans-esterification (from DMT) The reaction is carried out at atmospheric pressure and temperature of 170°C at the start and 230°C at the completion.The reaction is an endothermic one. Excess of ethylene glycol is used and methanol is removed as vapour to shift the reaction equilibrium to the right. The catalysts used by this are oxides of antimony or organic compounds of metals such as calcium, magnesium, zinc, manganese or cobalt.

(b) Polycondensation

The resulting monomer is polymerised in the presence of antimony catalyst by the polycondensation reaction. Here titanium dioxide is added as a delustering agent. The monomer is transferred to the polymerisation auto-clave and the temperature is raised to 280°C. The pressure is reduced to below 1.00 mm Hg absolute. The reaction in the polymerisation reactor is carried out under vacuum which is created by means of multi-stage vacuum ejector. During the reaction cycle, the melt must be agitated to cause a more intense and complete separation of the ethylene glycol formed during the reaction. The viscosity of the melt, an important parameter, is monitored by the speed of the agitation. After the desired molecular weight is achieved, the polymer is passed through the nozzle for cooling and pelletising. Here the molten polymer passing over the surface in the form of ribbon is solidified by use of a water spray and cut into desired size.

The solidified polyester strands are cut into chips and stored in different silos as per quality gradation after removing the water in a centrifuge. From the silos chips are transferred to spinning section where the chips are first dried to bring down moisture content to below 0.004%. Dried chips are fed into the extruder where they are heated and melted. The melt is filtered through a continuous polymer filter (CPF) and sent to

spinnerets. Care is taken to ensure that the polyester melt is evenly distributed through manifolds before it reaches the spinnerets. When the filaments extrude out of the spinnerets, they are quenched with conditioned air having c controlled laminar cross-flow to ensure that the filament does not break. These filaments are collected and wound on bobbins after application of spin finish oil. The yarns manufactured could be UDY (un-drawn yarn), POY (partially oriented yarn) or FDY (fully drawn yarn) depending upon the winder speed and heat setting methods. The yarn is further processed in draw-twisting and draw-texturising plants. Part of the texturised yarn is capitively used in the dyeing and twisting plants to produce dyed and twisted yarn.

The entire process is highly energy intensive, and hence any reduction in energy consumption has a significant impact on the cost of production and profitability.

Source of technology for PFY manufacturing is either from PFY manufacturing companies like Du-Pont, Toray, Teijin or from engineering companies like Zimmer, Lurgi, Dicier, Inventa, Chemtex, etc.

3.2 Energy profile

Polyester manufacturing is highly energy intensive process. The average net specific energy consumption for PSF/PFY in India is about 9181 Mcal/tonne.* Although no official data on the total energy consumption in this sector is available. However, a detailed analysis of the energy consumption pattern of five major PSF/PFY producers in India was carried out from specially designed questionnaire feedbacks and company annual reports. These five plants namely Reliance Industries, Century Enka, Raymond Synthetics, DCL Polyester and Baroda Rayon representing a market share of approximately 46%, had a total net energy consumption of about 1 x 10^9 Mcals in 1993-94. Assuming that the specific energy consumption of the sub-sector is the same as the five plants analysed, the total energy consumption for the sub-sector based on a production of 5.15 lakh tonnes works out to be about 4.71 x 10^6 Gcals in 1994-95.

Electricity is the most widely used form of energy in the sector. Fuel oils (including LSHS and HSD), along with coal in some plants, are primarily used to generate steam which is used in the process. The share of typical different energy forms in this sub-sector was analysed based on the information obtained for the five plants and is shown in **figure 3.4**.

As already mentioned, this sub-sector is highly energy intensive with estimated total net energy consumption of approximately 2.17 x 10^9 Mcals in 1993-94, and a specific

*Average of five plants in India - Reliance, Century Enka, Raymond Synthetics, DCL Polyesters and Baroda Rayon

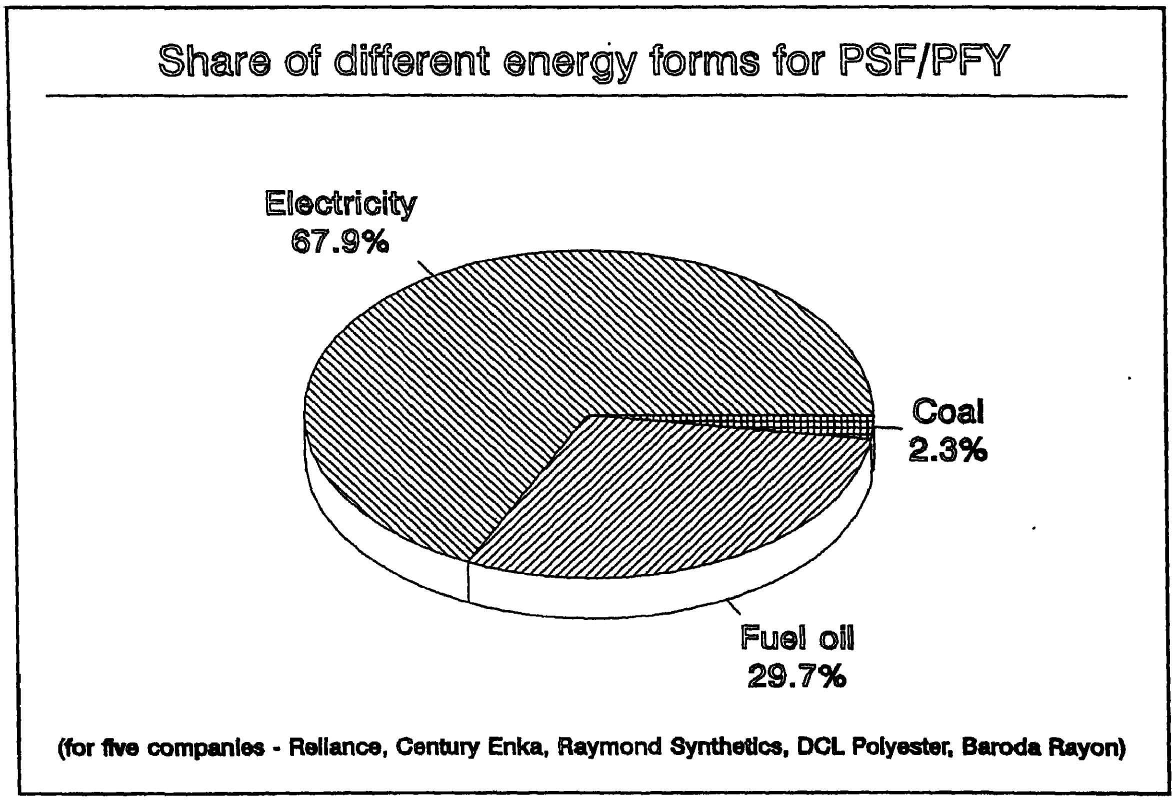


Figure 3.4 : Share of different energy forms for PSF/PFY in India

net energy consumption of 4514 Mcal/tonne. This does not take into account the energy requirement of preceding chemical operations viz. production of DMT/PTA and ethylene glycol. The total energy consumption inclusive of preceding chemical operations is about 1.7 times the net energy required for the manufacture of polyester fibre*.

There are a number of reputed suppliers of polyester technologies and each has its own energy consumption norms depending upon the plant design and process route. **Table 3.3** gives the specific energy consumption per tonne of PSF manufactured by different technologies. Since technology is changing at a very fast rate in this area, it may be noted that the figures given in the table 3.3 are of the early nineties and recent developments in process technology may have lead to further improvements over the figures provided below.

* Source : H Smith, World Power Conference 1968

Table 3.3. Specific energy consumption per tonne of POY of leading technology suppliers

	Zimmer A G, Germany	EMS-Inventa, Switzerland	Lurgi, Germany	Didier, Germany	Toray, Japan	Teijin Sei Ki, Japan
Electricity, kWh/t	1195	1046	1410	1740	970	1050
Steam, kg/t	924	605	370	350	1130	1800
Fuel oil, kg/t	112	87 3	92	72	-	110

Plant data of the major manufacturers of PSF/PFY in India is given in **Annexure II**.

3.3 Energy conservation opportunities

a) Upgradation of existing control systems which can result in substantial energy saving

Installation of advanced automation and control systems would lead to significant reduction of energy as accurate control over operating parameters could be maintained. The latest controls are advantageous also from quality control and safety point of view.

b) Continuous polymerisation reactors

The majority of existing polyester plants in the country have installed capacities between 20 TPD to 30 TPD. Earlier plants installed in the late sixties had capacities of 6 to 10 TPD. Batch polymerisation is still widely used, although the use of continuous polymerisation is steadily increasing. Continuous process of manufacturing polyester is much more energy efficient as it avoids the granulation stages and further melting of the polyester chips. Continuous process is advisable for plants having capacities of more than 20 TPD.

Apart from the energy efficiency, the other advantages of continuous process are given below:

- capital cost lower by 10-15%
- higher capacity utilisation
- reduced maintenance
- lower raw material consumption
- lower manpower requirement
- superior quality of the product

c) Complete recycling of ethylene glycol (EG)

In older plants, the EG was not recycled and was considered as a waste. However, in the latest technologies from Chemtech, Dupont and Zimmer, complete recycling of EG is

done. Recycling of EG is of primary importance in polyester production in terms of energy savings.

d) Installation of steam operated vapour absorption chiller in place of electrical operated compressor

Power consumption has also been reduced by use of steam operated vapour absorption chiller in place of electrical operated compressor in Reliance plant. The lithium bromide-water absorption refrigeration system is the best one available for utilising low level waste heat customarily rejected in petrochemical industry. The wastes from the trans-esterification reactor are at a temperature of 204 °C and the stack from the polymeriser is vented at a temperature of 232 °C. The waste heat could be used to chill water between 5 °C and 10 °C. The chilled water could be used for reducing energy consumption for cooling condenser water and crystallisers. As an example, the waste heat rejected from the overhead condenser for a distillation column, which amounts to 10.8 MBtu/hr (temp. range of 120 °C to 146 °C), can be used to chill 372 ton/hr of water at 7.2 °C in the case for chiller inlet water temperature of 12.2 °C. Assuming the price of chilled water at Rs 10 /ton, the payback on this system after taxes will be about 2 years. The above example clearly shows that this application is definitely viable in the present scenario.

e) Methanol recovery

Methanol is a by-product of polyester producing process through the DMT route. The crude methanol is distilled in the recovery unit with the help of steam. Improvement of the operating parameters of the distillation column could result in significant energy savings without additional expenditure.

In the Petrofils plant, the product-to-reflux ratio in the recovery unit was initially maintained at 1.0:5 and the steam consumption was 1.8 MT/MT of purified methanol. The operating parameters were modified without compromising the quality and purity of methanol by raising the product-to-reflux ratio to 1.1:5. This measure resulted in conservation of 0.8 MT of steam per tonne of methanol. The annual production of methanol was 3440 MT which resulted in an annual saving of Rs 9 lakhs at no extra cost.

f) Heat recovery from stack gas

There is a considerable heat loss through the flue gas of dryer, esterification reactor and boiler. The heat rejection from stacks to the atmosphere is second only to the heat losses through product cooling. Heat recovery could largely be achieved by adjusting the fuel/air ratio, installing waste heat boilers and air preheaters and utilising the convection zone of the furnaces.

g) Improving condensate recovery

By recovering the condensate from the entire plant (viz. dyeing plant, DMT area, poly ejectors) in a flash tank the condensate recovery could be improved from 20 to 45 %. The steam from the flash tank could be utilised in deaeration and preheating of boiler feed-water upto a temperature of 105 °C (**Figure 3.5**). Many plants have already gone for this measure which can be implemented with an attractive payback period.

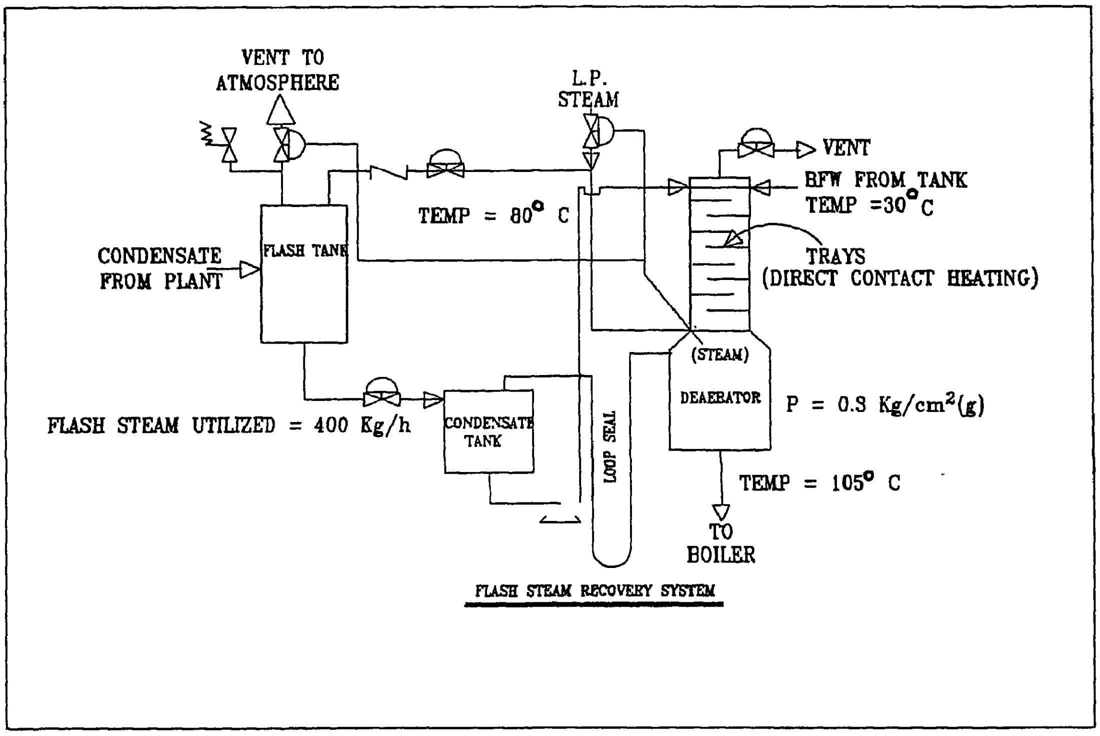


Fig. 3.5 : Flash steam recovery system

3.4 Environmental aspects

Minimum National Standards for petrochemical industries have already been given in table 2.4. Other aspects of pollution control specifically in a polyester industry are given in the following sections.

3.4.1 Solid Waste Recovery

As raw materials are becoming costlier, the present trend is to recycle the polyester waste. Recent technology for recycling waste includes cutting the polymer and fibre waste into small pieces to a specially designed conical extruder with the aid of force feeder. The melt is degassed in the extruder and thoroughly filtered before entering the granulation or alternatively is fed back to the polycondensation reactor. In PSF, one can use upto 3-4% waste but in PFY the polymer has to be purer and therefore 1-2% of the waste can be utilised.

3.4.2 Recovery of methanol from condenser vent

Chilled water circulation instead of cooling water in methanol vent condensers, reduce the methanol losses substantially.

3.4.3 Recovery of methanol from waste water

Methanol could be recovered from waste water by installing a distillation column to recover methanol from the effluent stream of the waste water. A case study of a waste water treatment plant in a polyester fibre and film plant is given below.

The waste water from a petrochemical plant which produces polyester fibre and films and the polystyrene industries are treated by an activated sludge plant. A typical plants consisting of equalisation basins, biological oxidation basins, clarification, dissolved air floatation, polishing ponds and filtration is shown in **figure 3.6**. The facility produces an effluent which contains 8 mg/l BOD and 11 mg/l suspended solids while removing 98 percent of the TOC (total organic carbon) present. A unique management strategy is employed in the facility. Each production unit is held accountable for the wastes they generate. Waste treatment costs are charged back to the individual production units based on the amount of organics discharged to the treatment plant. This system reduce waste loads and production losses.

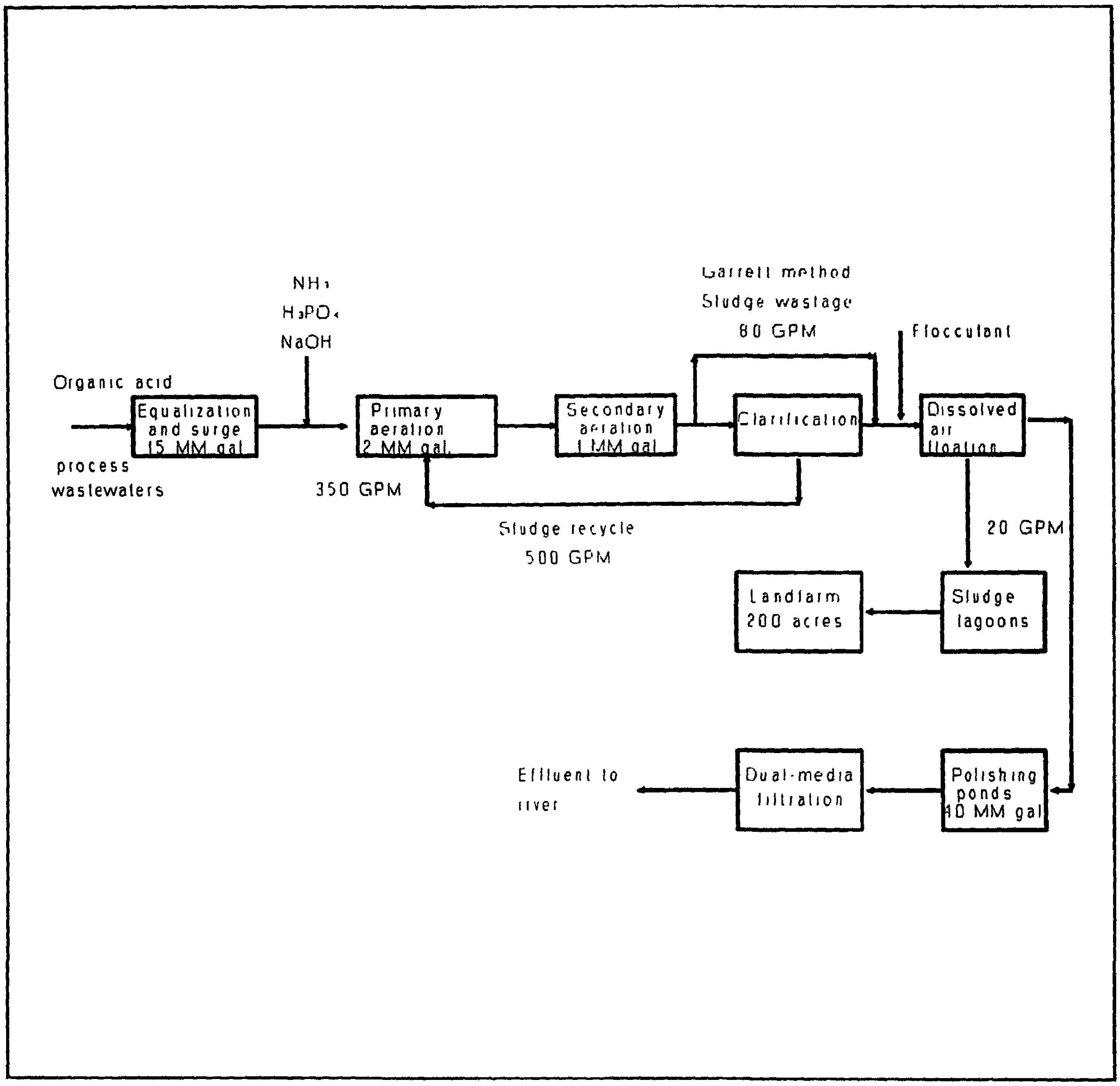


Fig. 3.6 : Waste water treatment flow diagram.

CHAPTER 4

Conclusion

In this study, a detailed review was carried out with regard to two downstream petrochemical products, namely, PVC and PSF/PFY. The petrochemical plants in India were build over a period of 30 years, employing different technologies which are not necessarily energy optimised. The industry consists of large number of sub-optimal sized plants based on old technologies. Technology upgradation and cost reduction is considered inevitable for the growth and success of the industry in coming years.

In the changing scenario, market forces will drive the industry towards energy conservation and pollution abatement. The extent of energy saving potential in the petrochemical sector has been estimated at 10-15%. The energy saving potential could be more, depending on the age of the plant and general operating practices being adopted by the plant personnel. In most of the plants, there is always scope to optimise process parameters and recover waste heat by adoption of advanced energy conservation techniques such as process simulation.

An analysis of the sector and its comparative assessment with the other sectors covered under the study, indicates that it is not a suitable candidate to be considered for the phase II of the project. This is primarily because the sector scores low on the absolute energy consumption and environment improvement criteria. However, some selected details of few plants under the sector are provided in annexure II. A select list of organisations involved in providing technical support to the industry is given in annexure III.

Annexure - I

Plant data of major PVC producers

Name of the plant	:	National Organic Chemical Industries, Thane Belapur Road, PB 73, Thane 400 601
Fax no.	:	022 7692056
Year of commissioning	:	1968
Ownership	:	Private
Installed capacity of PVC	:	21,500 TPA
Production 1993-94 (TPA) of PVC	:	25,328
Actual Energy Consumption		
1993-94	:	
Steam - M.P. (T)	:	22,335
Steam - L.P. (T)	:	15,970
Electricity (kWh)	:	1,42,73,631
Specific energy consumption		
Steam (t/t)	:	1.512
Electricity (kWh/t)	:	563.5

Source : Reply to questionnaire

Name of the plant	:	Indian Petrochemicals Corporation Limited, P.O. Petrochemicals Township, Vadodara 391 345
Fax No.	:	0265-372723
Year of commissioning	:	1984
Ownership	:	Public
Installed capacity of PVC	:	55,000 TPA
Production 1993-94 (TPA) of PVC	:	50,400
Actual Energy Consumption 1993-94		
Steam (T)	:	55,440
Electricity (kWh)	:	10,332,000
Specific Energy Consumption		
Steam (t/t)	:	1.1
Electricity (kWh/t)	:	205

Source : Reply to questionnaire

Name of the plant	:	**DCW Limited,** **Sahupuram, Chidambaranar, Tamil Nadu**
Year of commissioning	:	1972
Ownership	:	Private
Installed capacity of PVC	:	42,000 TPA
Production 1993-94 (TPA) of PVC	:	41,909
Actual Energy Consumption 1993-94		
Furnace Oil (K.L)	:	2820.77
Electricity (kWh)	:	171,230,000
Specific Energy Consumption		
Fuel Oil (KL/t)	:	0.06
Electricity (kWh/t)	:	402

Source : Annual Report 1994-95

Name of the plant	:	**Reliance Industries Limited,** **Village Mora, Bhatha P.O.,** **Surat-Hazira Road, Surat, Gujarat 394 510**
Year of commissioning	:	1991
Ownership	:	Private
Installed capacity of PVC	:	135.000 TPA (1994-95) 100.000 TPA (1993-94)
Production 1993-94 (TPA)	:	170. 304
Actual Energy consumption 1993-94		
Gas (SM^3)	:	21.458.304
Electricity (kWh)	:	77.318.016
Specific energy consumption		
Gas (SM3/t)	:	126
Electricity (kWh/t)	:	454

Source: Annual report 1994-95

Name of the plant	:	**DCW Limited,** **Sahupuram, Chidambaranar, Tamil Nadu**
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Gas (SM^3)	:	21,458,304
Electricity (kWh)	:	77,318,016
Specific energy consumption		
Gas (SM3/t)	:	126
Electricity (kWh/t)	:	454

Source: Annual report 1994-95

Name of the plant	:	**Raymond Synthetics Limited, Karchana, U.P.**
Ownership	:	Private
Installed capacity of PFY	:	16,350 TPA
Production of PFY in 1993-94	:	16007 tonnes
Actual Energy Consumption 1993-94		
F.O/LSHS (t)	:	5827.71
Electricity (kWh)	:	52,409,622
Specific energy consumption:		
F.O/LSHS (t/t)	:	0.364
Electricity (kWh/t)	:	3274

Source: Annual Report 1993-94

Name of the plant	:	**DCL Polysters Limited, Mouda, Maharashtra**
Ownership	:	Private
Installed capacity of PFY	:	22,000 TPA
Production of PFY in 1993-94	:	21,537 tonnes
Actual Energy Consumption		
1993-94		
F.O/LSHS (t)	:	1645
Coal (t)	:	5147
Electricity (kWh)	:	23,600,000
Specific energy consumption		
F.O/LSHS (t/t)	:	0.0764
Coal (t/t)	:	0.239
Electricity	:	1096

Source: Annual Report 1993-94

Name of the plant	:	**Baroda Rayon Corporation Limited, Surat, Gujarat**
Ownership	:	Private
Installed capacity of PFY	:	10,777 TPA
Production of PFY in 1993-94	:	8008
Actual Energy Consumption 1993-94		
F.O. (K.L)	:	769
Coal (t)	:	6727
Electricity (kWh)	:	2,72,00,000
Specific energy consumption		
F.O. (KL/t)	:	0.096
Coal (t/t)	:	0.84
Electricity (kWh/t)	:	3392

Source : Annual Report 1993-94.

Name of the plant	:	**Shree Synthetics Limited,** **PB No. 6, Ujjain 456 001, M.P.**
Fax No.	:	0734-50139
Ownership	:	Private
Installed capacity PSF/PFY/POY	:	9500 TPA
Year of commissioning	:	1973
Production in 1993-94 of PSF/PFY/POY	:	6017
Actual Energy Consumption 1993-94		
LSHS (K.L)	:	5714.8
F.O. (K.L)	:	689.6
HSD (K.L)	:	144
Electricity (kWh)	:	44,928,000
Specific energy consumption:		
LSHS (KL/t)	:	0.95
F.O. (KL/t)	:	0.115
HSD (KL/t)	:	0.024
Electricity (kWh/t)	:	7467

Source : Reply to questionnaire

Annexure - III

Consulting organisations in the field of petrochemical sector

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i) The Petrochemicals Management Development Institute
Indian Petrochemicals Corporation Limited (IPCL)
P.O. petrochemicals Township
Vadodara 391345

ii) Engineers India Limited,
1 Bikaji Cama Place,
New Delhi.

iii) Humphreys & Glasgow Consultants Pvt. Ltd.
Gammon House,
Veer Savarkar Marg,
Prabhadevi. Bombay 400 025.

iv) Chemtex Engineering of India Ltd.
Nirlon House.
2nd floor. 254B,
Dr. Annie Besant Road,
Bombay 400 025.

Bibliography

1. DSIR, 1990. Technology in Indian Dimethyl Terephthalate (DMT) and Polyester Staple Fibres (PSF) Industries, A status report prepared under the national register of foreign collaborations. Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India, February 1990.
2. DSIR, 1991. Technology in Indian Poly Vinyl Chloride Industry, A status report prepared under the national register of foreign collaborations. Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India. October 1991.
3. DSIR, 1990. Technology in Indian Polyester Filament Yarn Industry, A status report prepared under the national register of foreign collaborations. Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India, February 1990.
4. GOI, 1995. Annual Report. Ministry of Chemicals & Fertilizers, Government of India, New Delhi, 1994-95.
5. Reliance Industries Ltd. Twenty-first Annual Report 1994-95.
6. CMIE, 1994. Market & Market Shares. Centre for Monitoring Indian Economy, February 1994.
7. DCW Limited. Annual Report 1993-94.
8. The Baroda Rayon Corporation Ltd. Annual Report 1993-94.
9. DCL Polyester Ltd. Annual Report 1993-94.
10. Raymond Synthetics Ltd. Annual Report 1993-94.
11. Vergara W. and Babelon D. 1990. The Petrochemical Industry in Developing Asia. A review of the current situation and prospects for development in the 1990s. World Bank technical paper number 113, Industry and Energy Series. 1990.
12. CPCB, 1989. Minimal National Standards Petrochemicals Industry (Basic and Intermediates). Central Pollution Control Board, New Delhi, 1989.
13. The Hindu, 1995. Survey of Indian Industry.
14. TERI, 1995. Sector study report on Energy Efficiency in the Indian Petrochemical Industry submitted to Industrial Credit and Investment Corporation of India Ltd., Bombay. Tata Energy Research Institute, New Delhi, September 1995.